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DIRECTORATE OF FISHERIES

REPORT No. 15/1984

A STUDY OF THE COMMON MUSSEL

by

Nysaether, Liv Barratt

Central Laboratory

Quality Control Division

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Bergen, December 1984

FOREWORD

This report concerns an assignment carried out for the Common Mussel Committee. The assignment was part of the Committee's "Project for the Development of Common Mussel Culture as an Industry". The Project was financed from the public budget, CH. 552.72.2.36, Ministry of Labour and Local Government. The Hordaland Chief Fisheries Officer was chairman of the Common Mussel Committee.

The Quality Control Division of the Directorate of Fisheries was responsible for the technical and administrative aspects of the study.

The chemical, bacteriological and sensory studies were carried out at the Directorate's Central Laboratory, the tracer metal analyses at the Directorate's Nutrition Institute, and the analyses for shellfish poisons at the Institute of Food Hygiene, The Norwegian Veterinary College.

Liv Barratt Nysaether, M.Sc., was employed as a scholarship recipient from 01.11.1981 to 15.08.1983 at the Quality Control Division to work on this project. She also wrote the report.

Central Laboratory,
Bergen, December 1984

N. Losnegard

Liv. Barratt Nysaether

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SUMMARY (Page 3)

Common mussels from a commercial breeding facility were studied for one year. The purpose of the study was to establish quality criteria for common mussels and to determine how the quality of the mussel changes during the year, as well as determining the storage life of the mussels in various storage conditions.

The seasonal variations were studied by determining the mussels':

- content of mantle waters
- food content and chemical composition.
- content of total volatile nitrogen and pH.
- sensory quality (smell, appearance, consistency, taste and general impression).
- sensory freshness and survivability in dry storage.
- total number of live bacteria, number of coliform bacteria and number of fecal streptococci.
- content of PSP (paralytic shellfish poison).

The samples were taken approximately once every seven weeks.

Qualitative changes for dry storage were studied by measurement of:

- mortality (percentage of dead mussels).
- water loss and mantle water contents.
- content of total volatile nitrogen and ninhydrin reactive substances.
- pH.
- sensory quality.
- total number of live bacteria.

Two storage temperatures were used: 3° and 10°, for periods of up to 19 days. The mussels were inspected ever third or fourth day during the storage period.

On the basis of the general conclusions from this study, the problems surrounding the use of mussels as foodstuff, and with regard to what is common practice on foreign common mussel markets, an attempt has been made to develop guidelines for the breeding and handling of common mussels. As well, some criteria which can be used to describe the mussels and to determine their quality have also been developed. With regard to the values for the criteria selected, these are built on a relatively limited data base and therefore require additional supporting data. They may also require re-evaluation in the light of any further studies of the common mussel.

1) Breeding areas for the common mussel shall not be contaminated by sewage or industrial waste to such an extent that the content of indicating bacteria, heavy metals or other hazardous pollutants exceed the limit values presented in applicable international regulations. Before potential breeding areas are used they should be investigated with regard to pollution in accordance with pre-determined investigation protocols and accepted methods of analysis. The results from such investigations can be used to establish whether an area is suitable for breeding of common mussels for human consumption. (Page 4)

2) The cold part of the year (October/November - March) is apparently the best time for harvesting of the common mussel. This is the part of the year when the overall quality is best for the reason, among others, that the risk for paralytic shellfish poison is then lowest, the storage life of the mussel is the longest and the mussel survivability in dry storage is the greatest. As well, the food quality is good during this period.

3) During harvesting, transport, storage, processing and packing, the mussels must be handled carefully and must be kept clean. This will prevent death and injury to the mussels, reduction in storage life and survivability, as well as preventing pollution. Storage space and packagings must be such that the mussels are protected against pollution and are provided with sufficient air and drainage.

4) Common mussels can be placed in dry storage for a period of three - four days at a temperature of 2 - 5°C with no significant reduction in quality, provided that they are harvested during the winter in "clean" areas and that they are properly handled. However, the storage life is reduced if the mussels have been cleaned and the byssus filaments have been removed. The reason is that such treatment causes water loss and stress.

5) The mussels should meet the following quality requirements.

(Page 5)

	Raw mussels	Steamed mussel flesh
Sensory	Both internally and externally the smell shall be fresh with no hint of odour of mud, oil or metabolic products from the mussel itself or from micro-organisms. The mussel shall not be covered by mud or filth. External, major growths of other organisms shall not be present.	The mussel flesh shall have an even, clear colour of good lustre. The smell and taste shall be fresh and sweet and characteristic of the common mussel. There must be no smell or taste of mud, oil, etc., or from metabolic products, either from the mussel itself or from micro-organisms. The consistency shall be resilient, firm and smooth.
Food content:	> 18 - 20%	
Mortality:	close to 0%	
Mantle water:	150 - 100 g/100 g of mussel flesh.	
*tot. fl. N:	<8 - 9 mg/100 g of mussel flesh	<4 - 5/100 g of mussel flesh
pH:	<6.4	<6.9
tot. no. of live bact.:	<50000/g of mussel flesh	
fecal coliform:	0	0
PSP:	0 (<400 ME/100 of mussel flesh)	0
Heavy metals, chemical	Below limits specified by Codex pollutants	

*The determination is less reliable for raw mussels than for steamed mussels and should therefore, as much as possible, be carried out on steamed mussel flesh in accordance with the procedures indicated under "Analytic Methods".

6) In order to ensure that common mussels sold for consumption are bred and handled in accordance with accepted guidelines and maintain the required standard, quality control procedures should be introduced for common mussels and common mussel products. Such procedures should incorporate the quality criteria mentioned above. Quality control inspections should be carried out in accordance with mandated investigation procedures and methods of analysis at various stages in the chain of production from the location of breeding to the consumer. It is particularly important that the inspections involve determination of heavy metals, chemical pollutants, fecal coliform bacteria and algae toxins. (Page 6)

When the mussels are harvested for consumption during a season when the mussels may contain algae toxins the inspection of the mussels with regard to these substances should be mandatory.

INTRODUCTION (Page 7)

On the basis of their experience with mussels as a foodstuff, a number of countries have introduced regulations and guidelines for the breeding and processing of mussels, including quality control of mussels and mussel products.

In addition the CODEX ALIMENTARIUS COMMISION has developed a recommended international code of hygienic practice for molluscan shellfish.

In Norway the common mussel has had little importance as a foodstuff and the sales of mussels on the Norwegian market have been sparse. However, recent years have seen an interest in developing the breeding of common mussels for nutritional purposes, and a number of breeding facilities for the common mussel and for oysters have been established. Most of these facilities are still in the developmental stage and will, in the beginning, only provide a limited quantity of mussels. However, in the long term, as experience is gained, an increase on the Norwegian market of common mussels can be expected.

The quality of the mussels is determined by a number of factors, such as size, food content, smell, taste, appearance, consistency, freshness, storage life and hygienic standards. These are the result of the environment and its influence during the growth of the mussel, age, harvesting season and the treatment the mussel receives on its way to the consumer.

A law, dated 28 May 1959, concerning quality control of fish and fish products, provides the authority for establishing regulations for mussels and mussel products (molluscs). Detailed regulations regarding processing and sales of mussels, as well as standards for quality and hygiene, do not currently exist.

Until such regulations are available the applicable regulations, (Page 8) dated 13 May 1980, concerning shellfish and molluscs apply. They provide the authority to undertake inspections of such products to ensure that an acceptable hygienic standard is maintained and that they are processed in approved facilities.

During the last two years, against the background of an increasing interest in commercial mussel breeding, the Quality Control Division of the Directorate of Fisheries has been gathering the background material necessary to develop detailed quality regulations for mussels and mussel products. The purpose of this work has been to develop regulations, standards and inspection procedures suitable for the Norwegian environment, while at the same time considering the international requirements for standards of such products.

As a part of this work the Central Laboratory has carried out laboratory studies of the common mussel. These studies were planned and the results presented, from the viewpoint of problems related to "the common mussels as an article of food".

The purpose of the laboratory study was to establish:

- quality criteria for mussels, including the limit values for good quality.
- the criteria required for the growth environment of the common mussel.
- whether, and to what extent, the quality varies with the seasons with regard to harvesting and determination of the best season for harvesting.
- whether, and to what extent, the quality changes during storage, and establishment of the requirements for storage of the common mussel.
- the storage life of the common mussel.

It was also intended that this laboratory work would lead to knowledge of the product would create the necessary expertise.

Emphasis was placed on investigation methods which would be (Page 9) suitable for routine inspections. Because of the need to adjust the study to a practical amount of study material, and given the available capacity of the laboratory, the study was carried out using a comparatively limited amount of samples. This must be considered when conclusions are drawn regarding the results of this study.

DESCRIPTION OF THE COMMON MUSSEL (Page 10)

The common mussel belongs to the Mollusca group of invertebrates. The mussel is characterized by its mantle which separates the two shells from each other. The latter are hinged in the back and there are two muscles which keep the shells closed. When the muscles relax the shells open by means of the elastic hinge. The mantle surrounds the mantle cavity. In this cavity are located the gills. The heart and intestine are on the back side. The mantle cavity is usually filled with water which here is called mantle water (shell liquid).

A muscular foot provides the means for limited movement. A gland in the foot produces byssus filaments which are used to attach the mussel to its foundation. Figure 1 shows a cross-section of a common mussel.

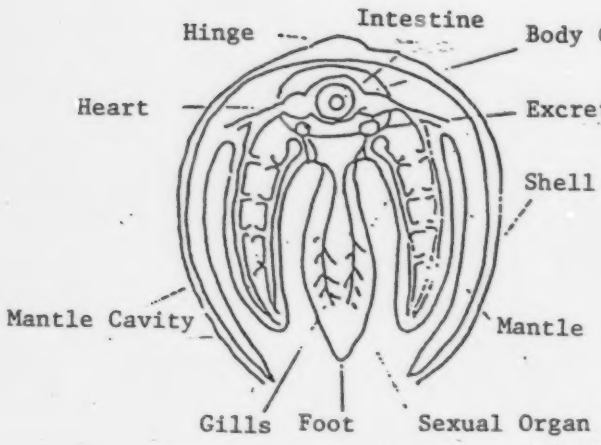

Fig. 1. Cross-section of a common mussel

The common mussel takes its nourishment from the sea. The gills function both as a pump and a filter. This nutritional method requires that great amounts of water be pumped through the gills. The mussels can therefore also accumulate bacteria, viruses, heavy metals or other pollutants if such are present in the water. During certain periods of the year, poisonous dinoflagellates may occur in the water. These may accumulate in the mussels and lead to food poisoning if they are eaten. (Page 11)

Metabolic waste and indigestable particles are separated in the mantle cavity and ejected by outflowing water.

The common mussel is unisexual. The female mussel has red eggs and the male mussel has yellow/white sperm. The sexes can be identified using this difference in colour. Spawning usually occurs in May - June and continues through the summer; however, the specific time varies from place to place and also slightly from year to year. Following fertilization larvae are developed. These live freely in the water for some weeks. The larvae then attach themselves to some object, using the byssus filaments. Mussel growth is dependent on such factors as temperature, availability of nutrients and salinity. These factors will vary from place to place.

Common mussels which are sold as food are most often bred in cultures. Breeding can be done using the following methods:

1) bottom culture
2) stake culture
3) line culture (from floats, buoys, etc.)

Line culture is the most common form in Norway.

SCOPE OF THE STUDY (Page 12)

The study was carried out during the period March 1982 - June 1983. The work was divided into two phases:

March - August 1982
- selection of breeding facilities
- development of plans and schedules for the study
- determination of material requirements, treatment methods, storage conditions and methods for testing and analyses
- testing and selection of quality criteria
- training of the participants in the sensory test panel.

August 1982 - June 1983 six samplings were taken from a single facility to establish:
- seasonal variations in mussel quality
- quality changes and storage life of mussels in various storage conditions.

Four series of sensory tests were also carried out during the study. These tests were carried out for the purpose of training the participants of the sensory test panel. In these tests the mussels were harvested at different dates, but given to the test panel on the same day. This provided an opportunity to compare mussels with different storage times.

Throughout the study mussels were taken at commercial breeding facilities. The storage series were established with live mussels and the mussels were stored dry for up to 19 days. During the storage period samples were taken of live mussels for chemical, physical, bacteriological, sensory and other tests. Such tests were made 6 - 7 times. (Page 13)

BREEDING SITES (Page 14)

During the period March 1982 - June 1982 samples were taken from the following sites:

Date	Site
15.3	Heimarkpollen, Austevoll
20.4	Busepollen, Austevoll
24.5	Busepollen, Austevoll

During the period August 1982 - June 1983 samples for the storage testing were taken from Jan Rossangs' breeding facility at Hindenes Fjord, Lindas. The storage series for this period were started 23/8, 4/10 and 15/11 1982, as well as 3/1, 7/3, 18/4 and 13/6/1983.

The mussels used for the training of the sensory test panel were obtained from Magnus Andersens' facility at Bruntveit, Reksteren. The sites of all the facilities are shown in Figure 2. Only the results from phase 2 are included in this report.

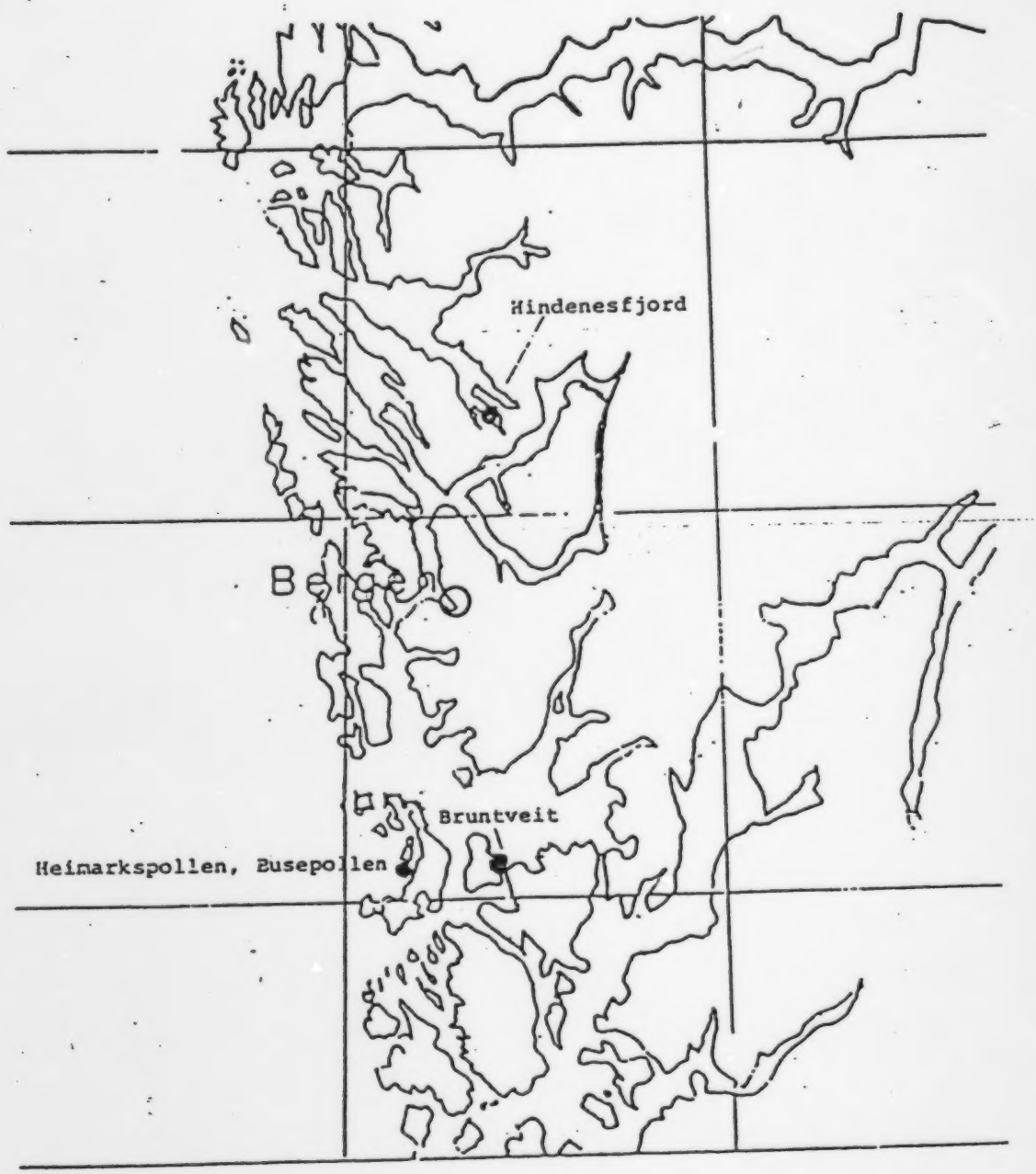

Fig. 2. Sites for breeding facilities used in the study.

TEST METHODS (Page 16)

Forty to sixty kg of mussels were harvested for each storage series. The mussels were harvested during Sundays and brought to the Central Laboratory on Monday morning. The storage series were also established on Mondays and the first tests and analyses of the mussels were carried out.

The storage series were established as follows: 2.5 kg of mussels, randomly selected, were placed in perforated plastic bags suspended in 3-litre plastic buckets. This storage method allowed both ventilation and drainage of the mussels, and the plastic bags provided the mussels a suitably moist environment. The mussels were cleaned before storage, and soft external organisms were removed without separating the mussels from each other, and without pulling the byssus filaments from the mussels.

The mussel samples were weighed and the weight was written on each individual bucket. The mussels were stored at temperatures of 3° and 10°C. During the storage period samples were taken for analysis in accordance with the following schedule:

Number of storage days at each sampling event:

1---3---5---9---12---16---19

For each sampling event one 2.5 kg sample was taken for each storage temperature. The mussels were then distributed for the various types of analyses. Parallel sampling was not done because such a procedure would require a large amount of samples and would also have exceeded the available capacity for analyses. Double testing of individual samples also had to be omitted for this reason.

The only exceptions in this regard were the chemical analyses for (Page 17) protein, carbohydrates, fat and dry matter. For these, two parallel samples were taken from a homogenized mussel flesh sampling.

The investigation and analyses were carried out both on raw and steamed mussel flesh. With the exception of the sensory tests, water loss, mantle water and mortality, all the tests were done from a homogenate of all the mussel flesh in the sampling. For a few storage series the mantle water was determined, and there was also one storage series which concerned the storage life of mussels which had been cleaned and for which the byssus filaments had been removed.

Tests were carried out with regard to the following:

water loss, mantle water

mortality

total volatile nitrogen (TVN)

pH

ninhydrin reactive substances (3 storage series)

sensory tests

bacteriological tests:

- total number of live bacteria
- coliform bacteria
- fecal coliform bacteria
- fecal streptococci

food content

carbohydrates

protein

fat

dry matter

metals.

The metal content was tested four times during the year. (Page 18) Carbohydrates, fat, protein, ashes and dry matter were tested at the begining of each storage period. The other parameters were tested during each sampling taken during the storage period.

ANALYTIC METHODS (Page 19)

Size. The maximum length of each mussel was measured with calipers. The shells were classified by size into groups; 40-45, 45-50, 50-55 and larger than 55 mm. The classification in groups was made to ensure that the testing was carried out on shells of similar size.

Mantle water and water loss. The water contained in the mantle cavity is here called mantle water (mussel liquid). The amount of mantle water in relation to the amount of mussel flesh was determined by collecting mussel flesh and mantle water from 25 mussels of the size group 50-55 mm in a beaker and then straining for 5 minutes. The mussel flesh and the mantle water were then weighed separately and the amount of mantle water was expressed as g/100 g of mussel flesh.

The total water loss of the mussels during storage was determined by weighing the mussel samples before and after storage and then calculating the percentage of water loss due to storage.

Mortality. From 100 randomly selected mussels, the number of dead mussels were counted and expressed as a percentage. Open mussels which do not close when the shell is struck were recorded as dead.

Food content. Thirty mussels (10 each from the groups 45-50, 50-55 and 55-60 mm, respectively) were cleaned with regard to impurities and external growth. They were then carefully washed and generally handled so that the mussels would not open and lose their mantle water. The mussel samples were then weighed and steamed for 6 minutes. The steamed mussel flesh was then removed from the shells and weighed. The percentage of steamed mussel flesh was then calculated:

$$\% \text{ food content} = \frac{\text{weight of steamed mussel flesh} \times 100}{\text{total weight before steaming}}$$

Sensory tests. The sensory tests were carried out by a panel of six (Page 20) persons. Each taster tested four raw and four steamed mussels. These mussels were larger than 55 mm.

Raw mussels were placed in plastic boxes covered with aluminium foil. The mussels were not cleaned nor washed.

Steamed mussels were served in the shell, wrapped in aluminium foil and placed between two warm plates, in order to provide a suitable temperature for tasting. It was particularly important that the mussels were warm when tasting for odour, since the smell quickly disappeared when the mussels were cooled. The mussels were steamed for seven minutes on a grill above boiling water. Before steaming the mussels were cleaned for both hard and soft external organisms, filth and dirt removed, scrubbed and thoroughly washed.

Each taster was required to assess each of the four mussels and to provide the descriptions for the following parameters:

Raw mussels: external and internal smell and total impression.

Steamed mussels: smell, appearance, taste, consistency (by rubbing the mantle between the fingers) and total impression.

The tasters also provided numerical values for each of these parameters. The scale used was from 9 - 1 in which 9 represented the best quality, 9 - 7 a less positive impression, 7 a neutral assessment and 7 - 5 an increasing extent of negative impression. The value of 7 would be the lower limit for a good commercial product. A value of 5 would indicate that the mussels are no longer edible nor acceptable commercially.

A sensory test of a storage series was terminated either when the (Page 21) average total impression of the test panel had reached 5, or when 10% of the mussels were dead.

pH was measured using a radiometer PHM 62 in a homogenate comprising 1 part mussel flesh or mantle water and 1 part 0.15 M KCE as indicated by Bendall (1973).

Total volatile nitrogen was determined using a diffusion method described by Conway and Byrne (1933).

Ninhydrin reactive substances were determined in a TCA-extract in accordance with Central Laboratory method no. 18. The TCA-extract was prepared by adding 1 part of homogenized mussel flesh, 2 parts of 10% TCA and by adding 9 parts of mantle water to 1 part of 60% TCA.

Carbohydrates were determined in accordance with a method by Gaye G. Sims (1978).

Fat was determined by the ethylacetate method, Central Laboratory method no. 36.

Protein was determined using the Central Laboratory method no. 1.

Ash was determined using Central Laboratory method no. 2.

Dry matter was determined using Central Laboratory method no. 3.

Metals were determined at the Directorate of Fisheries Nutrition Institute (Julshamn, 1983).

Bacteriological tests. The number of live bacteria was determined (Page 22) using the Central Laboratory method no. 41. Coliform bacteria was determined using the Central Laboratory method no. 31. Fecal coliform bacteria were determined in accordance with the Central Laboratory method no. 33. Fecal streptococci were determined in accordance with the Nordic Committee on Methods for Foodstuffs Technology method no. 68 (1978).

Paralytic shellfish poison (PSP) was determined in accordance with the Nordic Committee on Methods for Foodstuffs Technology method no. 81. The extracts were prepared at the Central Laboratory and sent to the Institute for Foodstuffs Hygiene at the Veterinary College of Norway for determination of PSP content.

RESULTS AND DISCUSSION (Page 23)

Sensory testing. Sensory testing was carried out for the purposes of:

- determine sensory characteristics and descriptions for the common mussel at various levels of quality
- evaluate quality as a function of season
- evaluate quality as a function of storage
- determine storage life for various storage conditions (time and temperature) and establish limits for allowable storage conditions
- determine limit values for chemical and bacteriological parameters
- develop expertise.

The relationship between grades of quality and descriptions of quality was developed as follows:

The testers were required to provide short descriptions and a grade for each of the parameters of: external and internal smell for raw mussels and smell, appearance, taste and consistency for steamed mussel flesh. On the basis of this material, and from discussions among the testers, the following table was developed with regard to grades and descriptions:

Raw mussels (Page 24)

GRADE	DESCRIPTION	
	External smell	Internal smell
9	fresh smell of sea water, seaweed, kelp and algae	fresh smell of sea water, characteristic of the common mussel
8	more neutral but continued fresh smell of sea water and seaweed	more neutral but continued fresh smell of sea water
7	neutral, less fresh, weak smell of low tide beach	neutral, less fresh
6	acrid smell of low tide beach and seaweed, slightly pungent	acrid, partly pungent
5	stinging, marshy, muddy, in part rotten, low tide beach and seaweed	stinging, pungent, nauseating, slightly rotten
4	rotten, spoiled, sewer-like	rotten, spoiled
3	rotten, spoiled, sewer-like	rotten, spoiled

Steamed mussel flesh (Page 25)

GRADE	DESCRIPTIONS			
	Appearance	Smell	Taste	Consistency
9	smooth, clear colour, good lustre	fresh, sweet, characteristic of mussels	fresh, sweet, characteristic of mussels	resilient, firm and smooth
8	smooth, clear colour, good lustre	fresh, sweet, characteristic of mussels	fresh, sweet, but less distinct	less resilient, smooth, not very moist
7	reduced lustre	fresh, neutral, less sweet	neutral, less sweet	moist, sticky
6	dull, discoloured	neutral, less fresh, slightly pungent	less fresh, neutral, slightly pungent	sticky, grainy
5	shrivelled, dull, discoloured	pungent, nauseating	pungent, bitter	grainy, leathery
4	shrivelled, discoloured	sewer-like, stinging, lightly spoiled	pungent, acrid, sour	leathery, rubbery
3	shrivelled, discoloured	sewer-like, stinging, spoiled	pungent, acrid, sour	leathery, rubbery

For the parameter "total impression" the following grading scale was (Page 26) developed:

TOTAL IMPRESSION	GRADE
Exceptionally good	9
Very good	8
Good	7
Less good	6
Not very good	5
Poor	4
	3

The sensory testing provided a comparatively large spread (standard deviation) in the grading of mussels which had been stored in identical conditions. The spread may be explained by the limited experience of the panel participants with regard to assessing the common mussel; however, it may also be explained by individual differences between mussels in the same sample.

If the spread is explained by limited experience, one would expect that the spread would diminish as the panel became more experienced. If the spread is explained by individual differences in the mussels, one could expect that the storage conditions (time or temperature) would lead to magnification of these differences until a certain limit when all the mussels would have gone bad.

To establish the course of this spread the mean standard deviation for total impression of each storage series was plotted as a function of storage series number (Figure 3 A). The mean deviation of total impression for all storage series was also plotted as a function of storage time (see Figure 3 B).

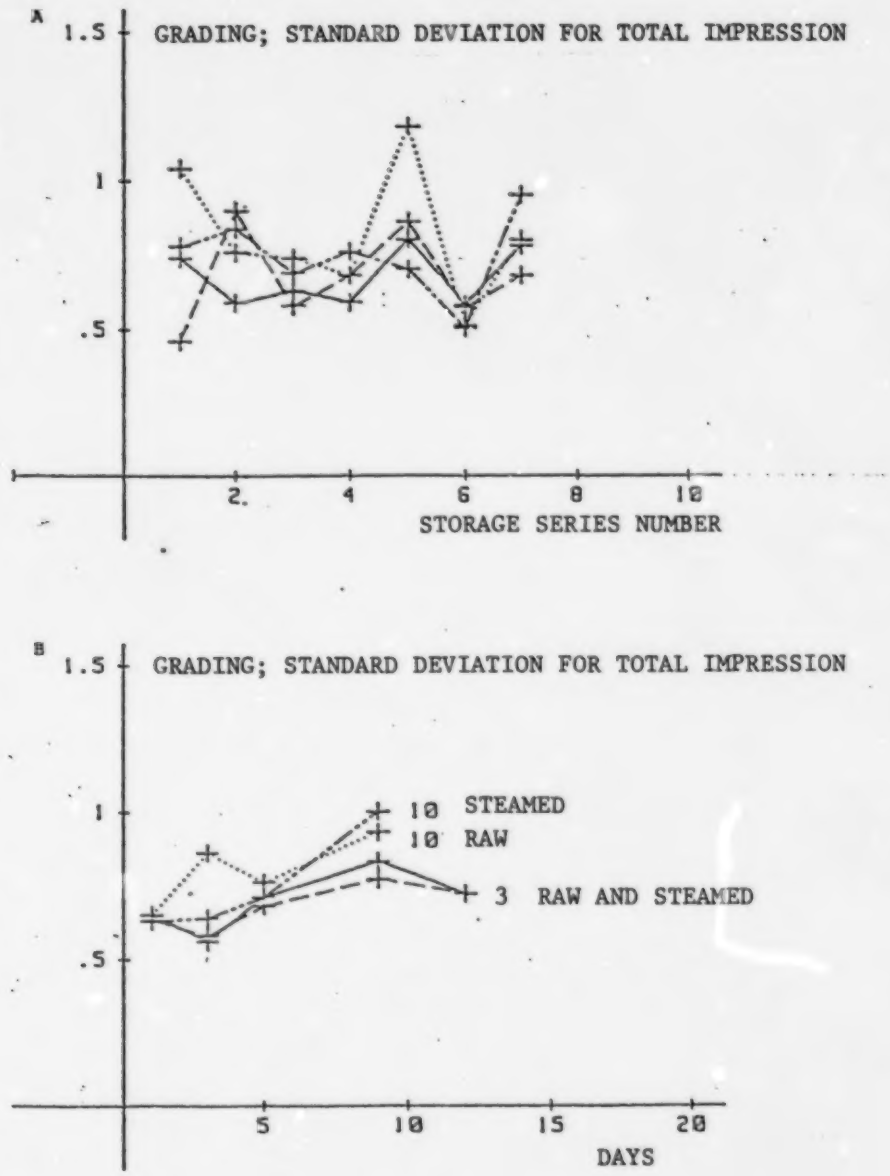

Fig. 3. A) Standard deviation for total impression as a function of storage series number.

B) Standard deviation for total impression as a function of storage time.

Figure 3 A shows no indication in standard deviation with increasing (Page 28) storage series number. One may also consider that the spread may be dependent on the season; however, whether such a correlation exists is difficult to prove. Figure 3 B does show that standard deviation is less at the outset of the storage period than at the end for both temperatures (3° and 10°). Standard deviation for the 10° mussel is generally higher than for the 3° mussels. Such a result may indicate that the spread is due to individual variations in the mussels. Figure 3 B also shows that the spread for the 3° mussels is slightly less at the end of the storage period. This would mean that the mussels had gone so bad that individual differences have been eliminated.

The large spread in the sensory data shows that it may be difficult to make sensory judgements with regard to storage conditions. However, Figure 3 B shows that a wide distribution of sensory quality of mussels may often, in itself, be a sign that the storage conditions are the cause of reduced quality.

Figures 4 A, B, C, D and E present test data for raw and streamed mussels stored at 3° at 10°.

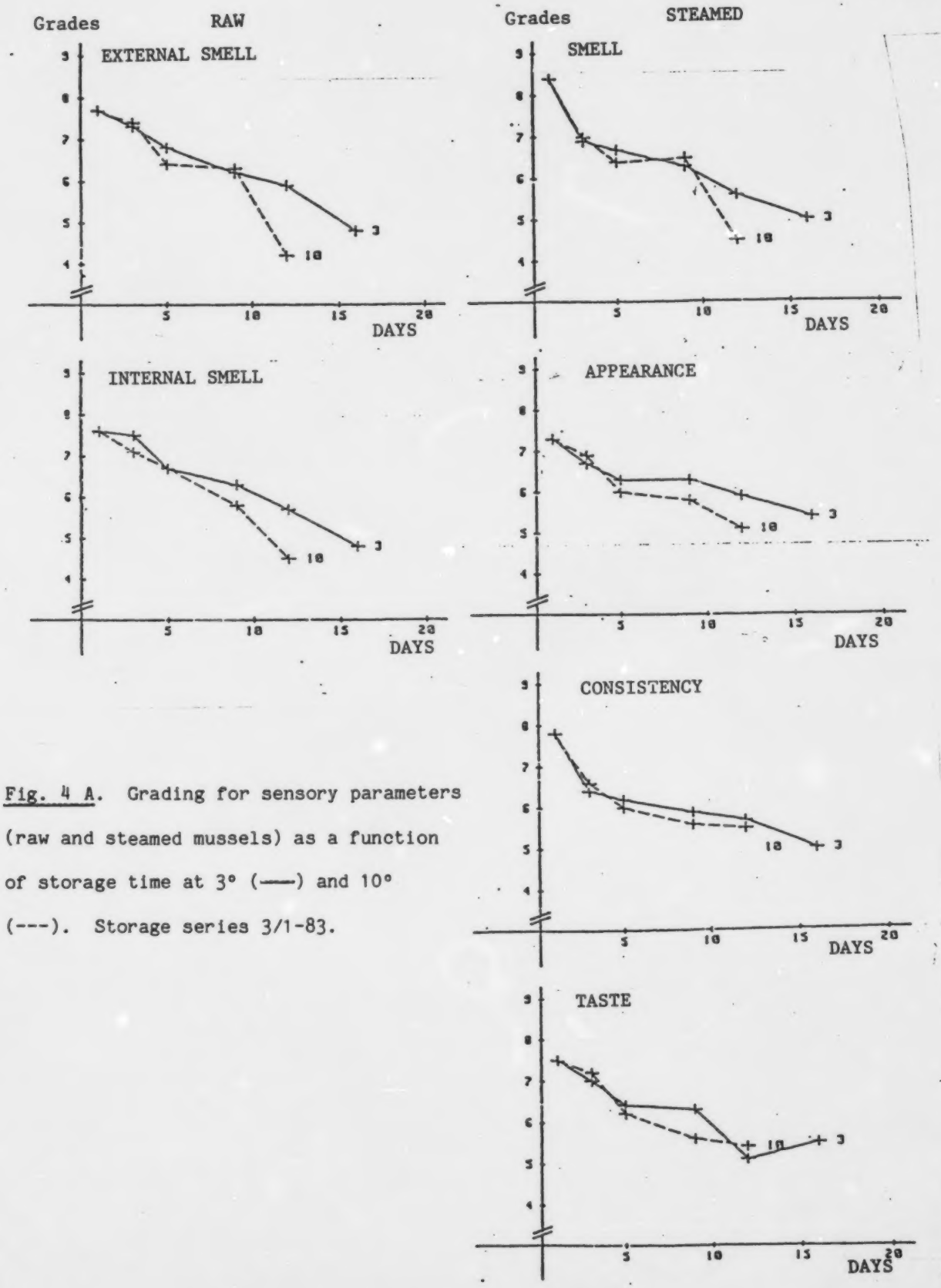

Fig. 4 A. Grading for sensory parameters (raw and steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 3/1-83.

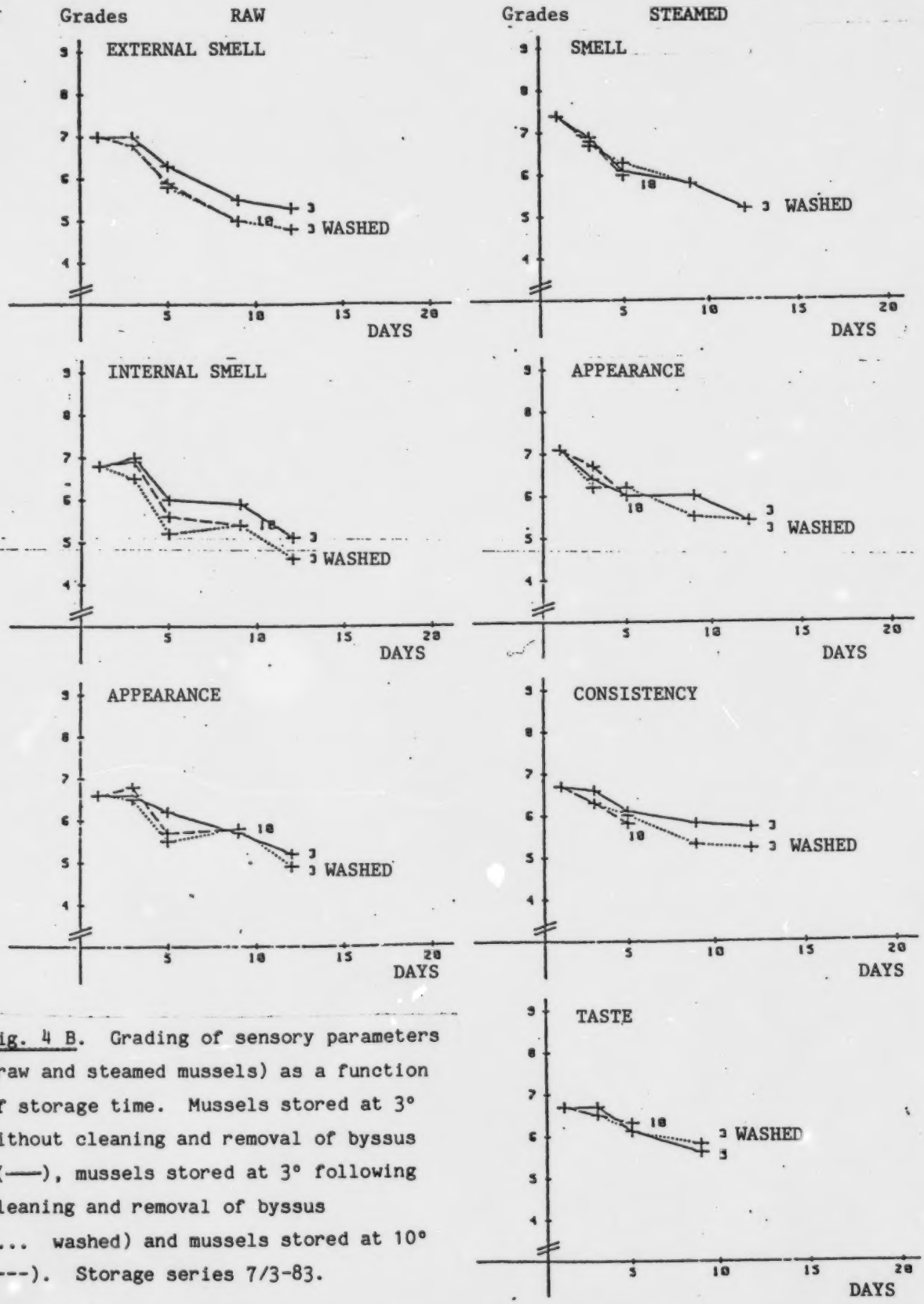

Fig. 4 B. Grading of sensory parameters (raw and steamed mussels) as a function of storage time. Mussels stored at 3° without cleaning and removal of byssus (——), mussels stored at 3° following cleaning and removal of byssus (... washed) and mussels stored at 10° (---). Storage series 7/3-83.

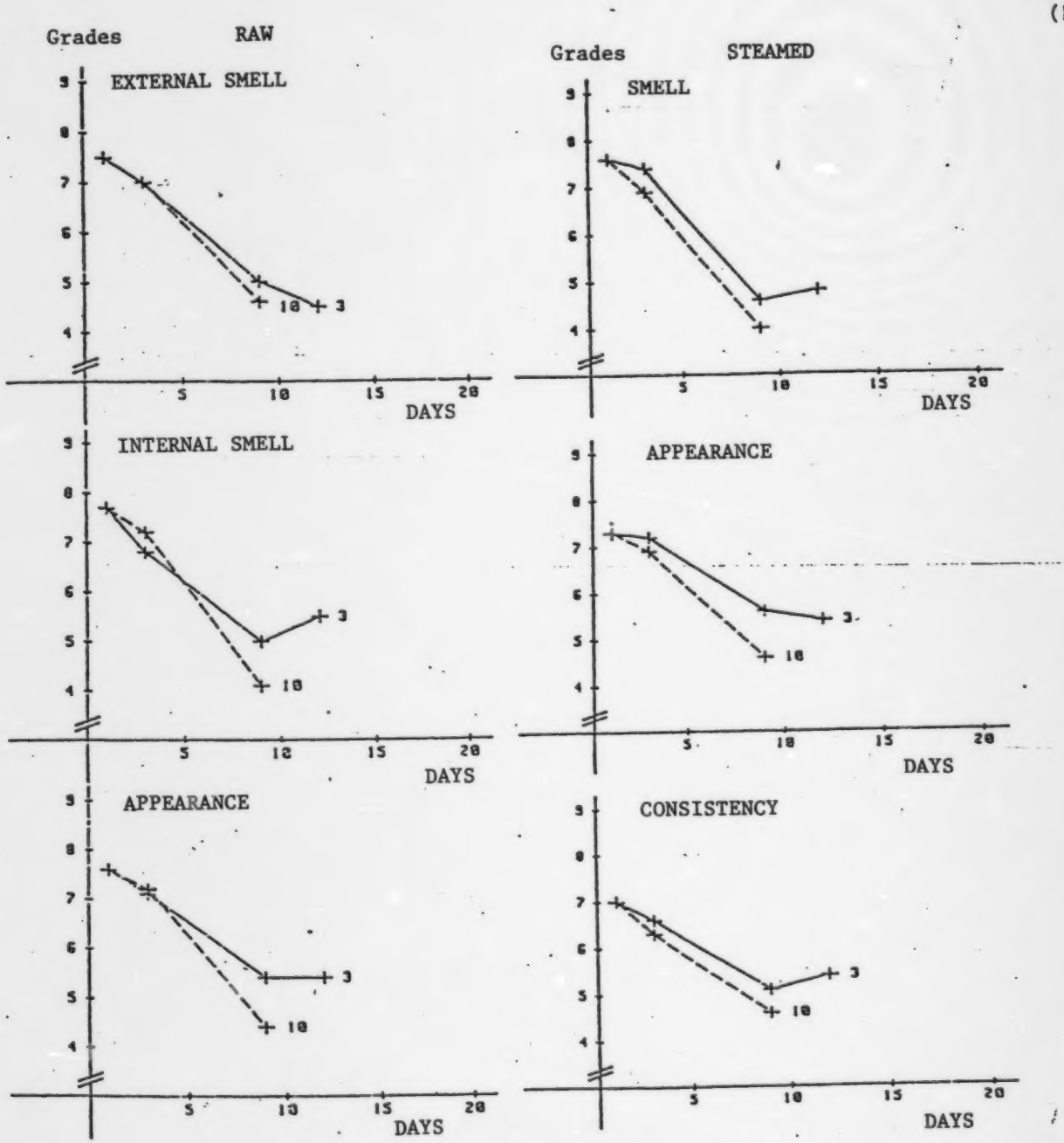

Fig. 4 C. Grading of sensory parameters (raw and steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 18/4-83.

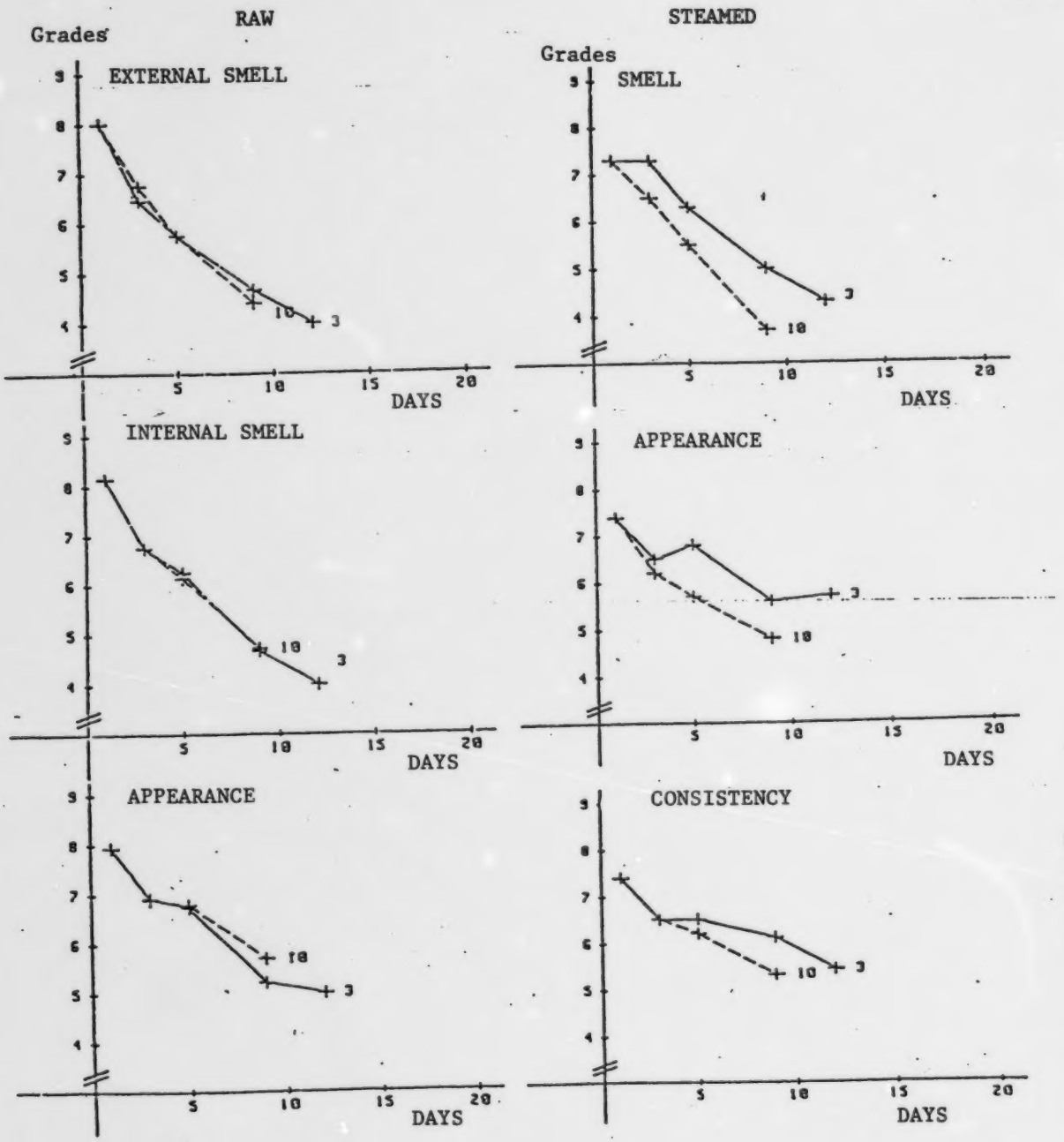

Fig. 4 D. Grading of sensory parameters (raw and steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 13/6-83.

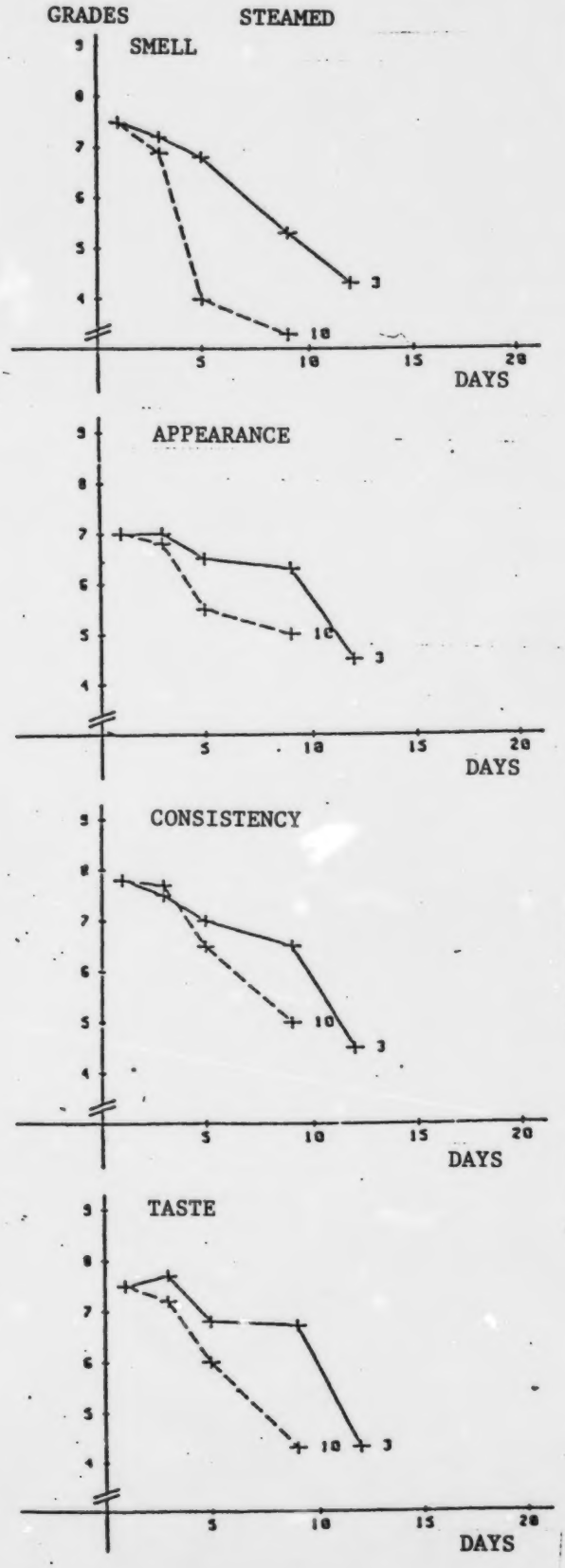

Fig. 4 E. Grading of sensory parameters (steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 23/8-82.

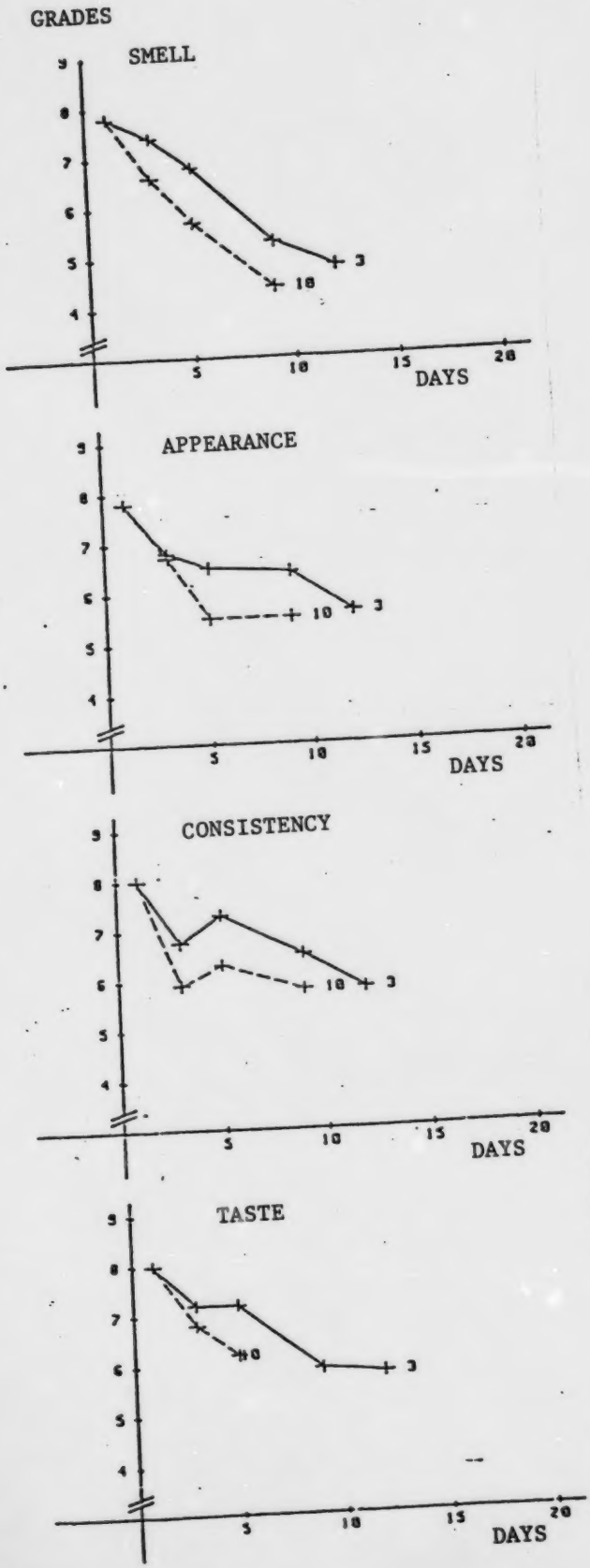

Fig. 4 F. Grading of sensory parameters (steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 4/10-82.

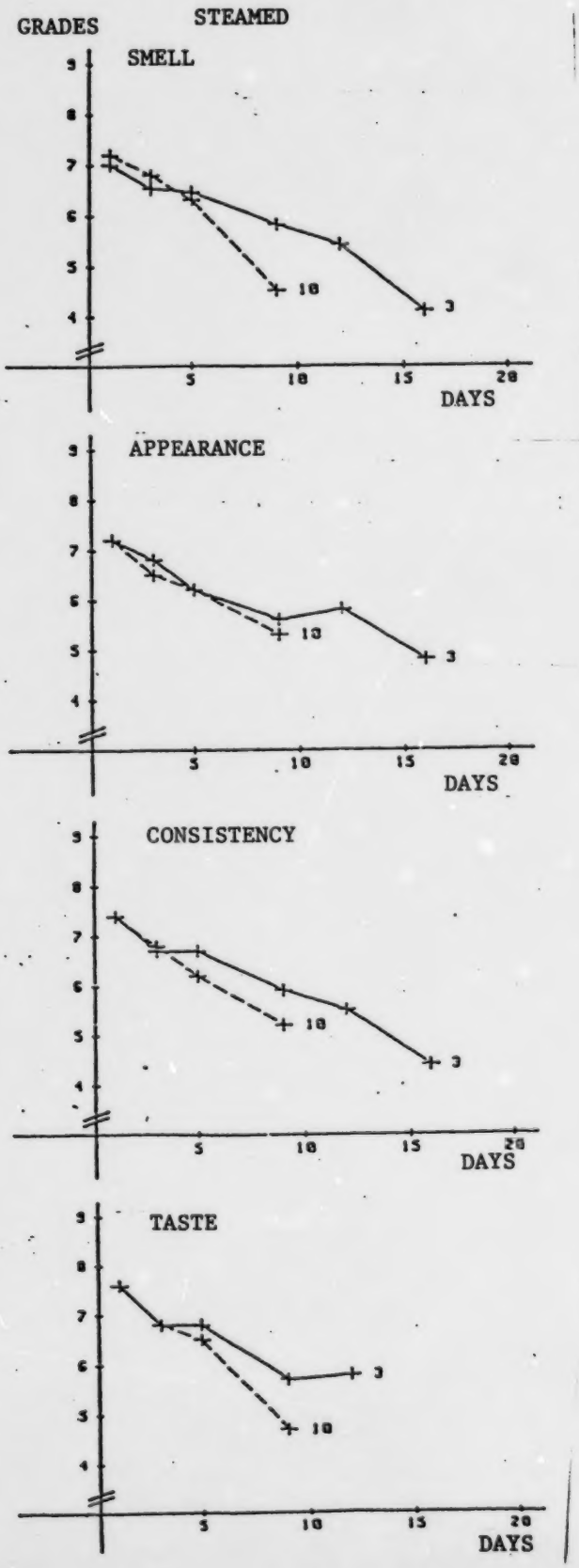

Fig. 4 G. Grading of sensory parameters (steamed mussels) as a function of storage time at 3° (——) and 10° (---). Storage series 15/11-82.

During the sensory testing, it was often very difficult for the tasters(Page 36) to determine which parameter was the most deciding when they determined the total impressions. It is therefore desirable to investigate the relationship betwen the grades for smell, appearance, taste and consistency, as well as the grades for total impression. To establish the sensory parameters which the panel had considered most important when they determined the total impression for steamed mussels, the mean value for total impression of all samples is presented as a function of the mean value for each of the parameters smell, appearance, taste and consistency. As well, correlation coefficients have been calculated (Fig. 5 A and B, Table 1).

Table 1 presents the correlation coefficients for the curves in Fig. 5 A and B.

Table 1

Correlation coefficients for comparison between the grades for the parameters of smell, appearance, taste, consistency and the grades for total impression.

	Correlation coefficient	
	3^{o}	10^{o}
	A	B
Smell	0.987	0.999
Appearance	0.985	0.982
Taste	0.999	0.999
Consistency	0.989	0.993

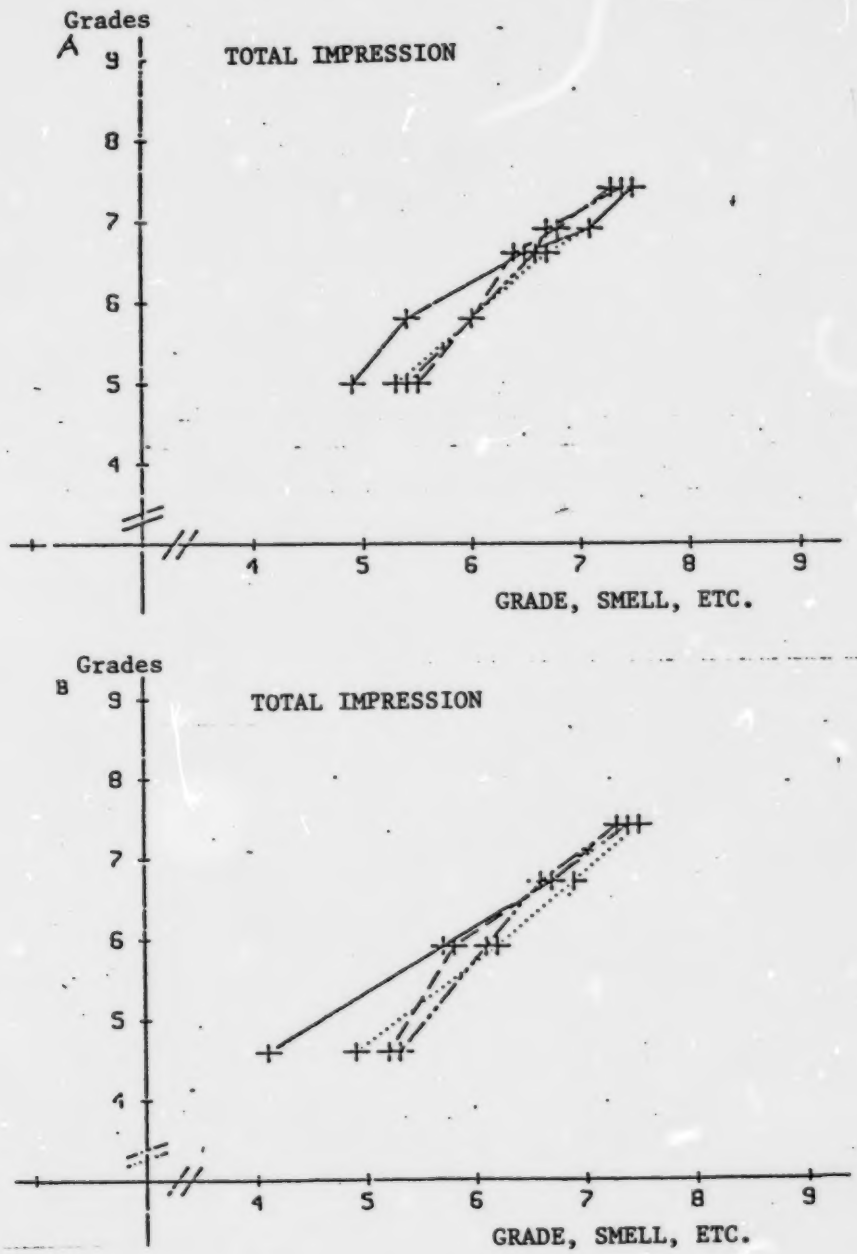

Fig. 5. Relationship between total impression and smell (——), appearance (---), taste (...) and consistency (——) for steamed mussels.

A) mussels stored at 3°.

B) mussels stored at 10°.

Table 1 shows that there is a comparatively good correlation between (Page 38) the total impression and the other sensory parameters. The result also shows that there is better correlation between taste and total impression than, for instance, between appearance or consistency and total impression. This is borne out by the discussions in the sensory test panel. All the participants were of the opinion that it was difficult to assess the appearance and consistency. In addition, the great disagreements regarding descriptions concerned these latter parameters.

With regard to raw mussels no attempt was made to find a correlation between total impression and the other sensory parameters. The reason for this was insufficient data.

Figures 6 A and B show a reduction in quality grading (total impression) for dry storage of all storage series for both raw and steamed mussels. The figures compare mussels stored at 3° and 10°C. With regard to storage series 7/3, a comparison is made between mussels which have been washed and had their byssus removed prior to storage and mussels which were stored without such treatment.

Generally the drop in quality occurs more rapidly for mussels stored at 10° than at 3°. This tendency is more marked after 3 - 5 days of storage. This can also be seen in Figure 6 C which indicates mean values of all storage series, with a comparison between 3° and 10°C for raw and steamed mussels. The correlation with regard to total impression is good. It can be seen that after 3 days of storage the raw mussel is given a lower grading than the steamed mussels. The difference is small and may be random. If there is difference, it may be caused by the elimination of some of the compounds which create a bad smell and taste by the steaming process.

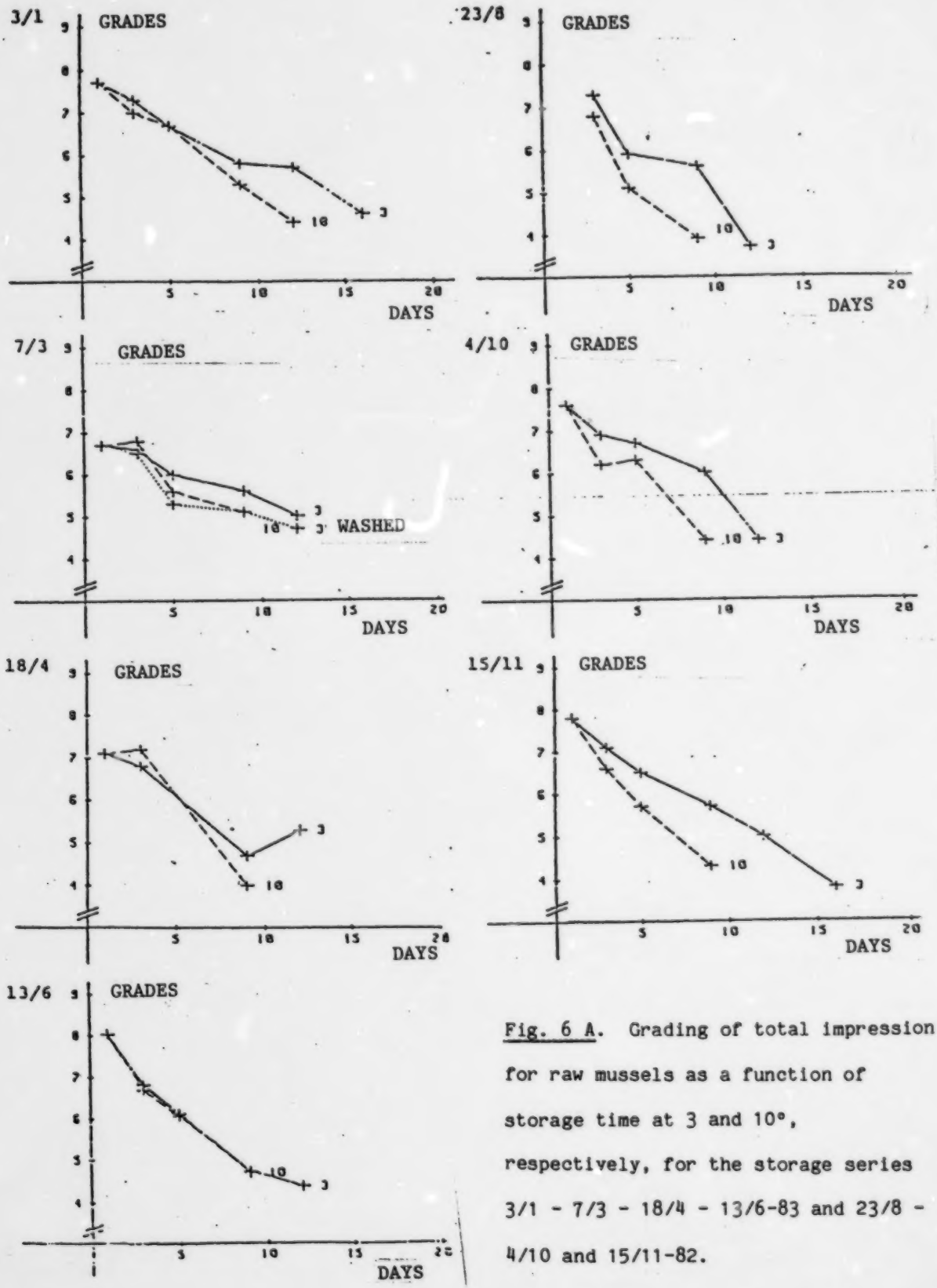

Fig. 6 A. Grading of total impression for raw mussels as a function of storage time at 3 and 10°, respectively, for the storage series 3/1 - 7/3 - 18/4 - 13/6-83 and 23/8 - 4/10 and 15/11-82.

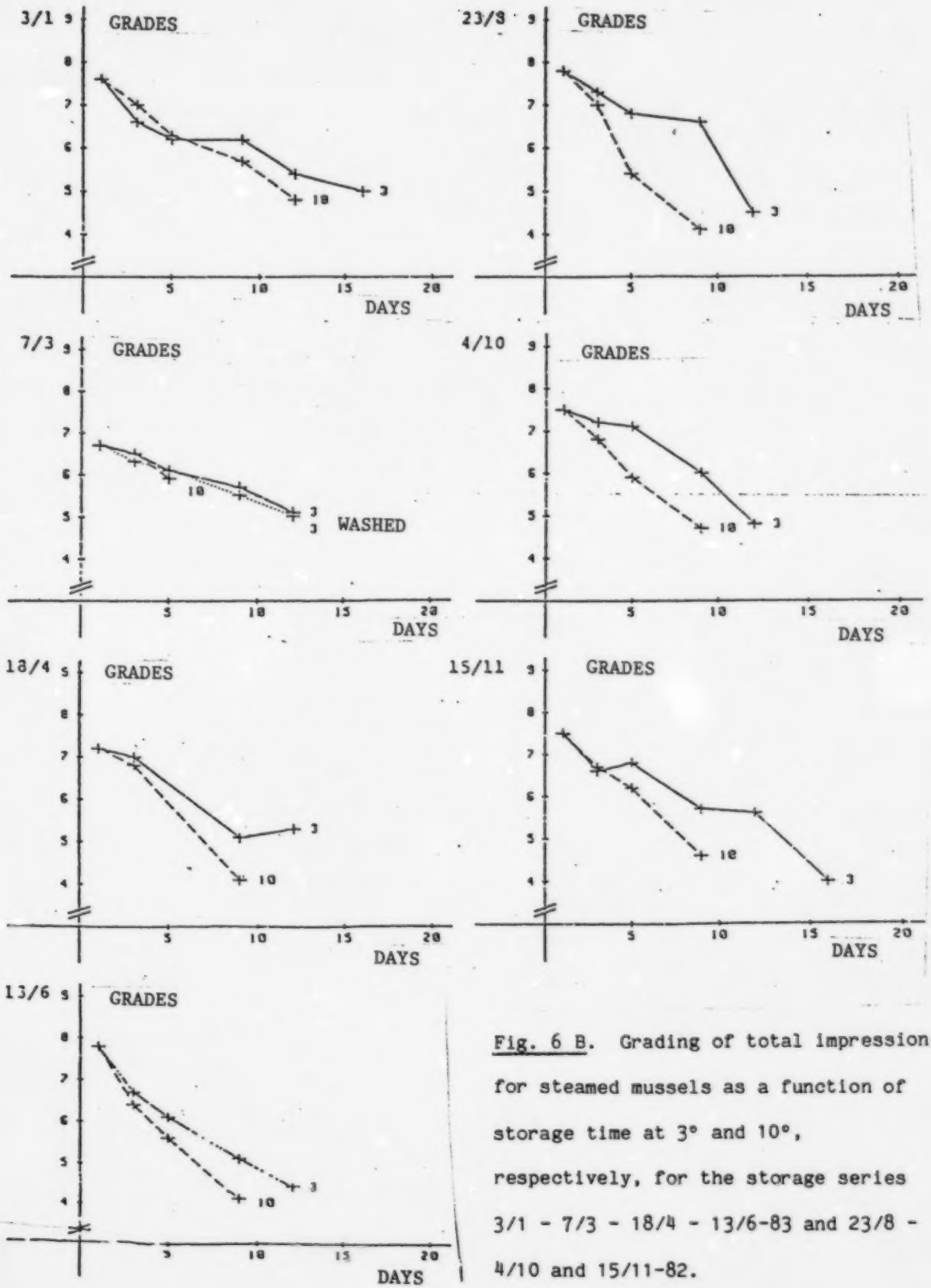

Fig. 6 B. Grading of total impression for steamed mussels as a function of storage time at 3° and 10°, respectively, for the storage series 3/1 - 7/3 - 18/4 - 13/6-83 and 23/8 - 4/10 and 15/11-82.

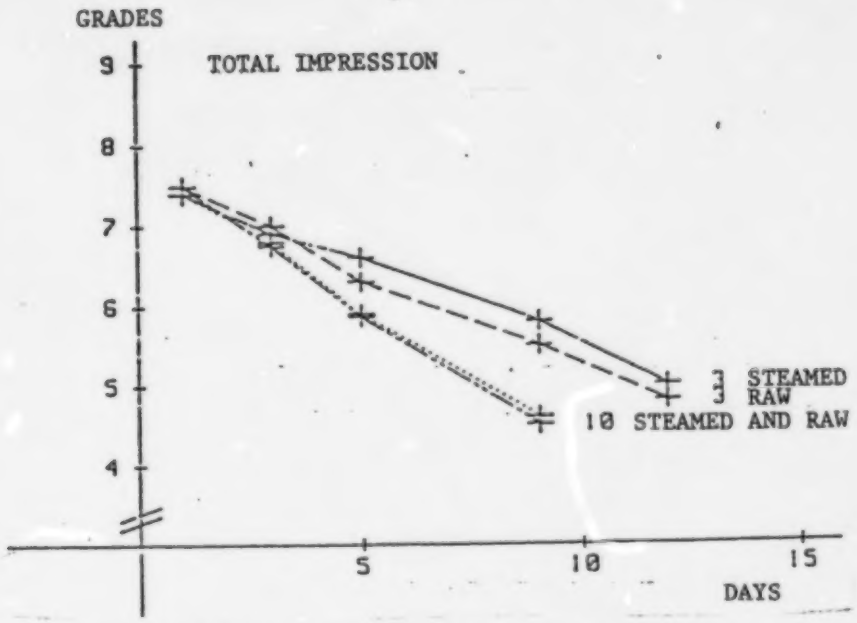

Fig. 6 C. Mean grading of total impression for raw and steamed mussels (all storage series) as a function of storage time at 3° and 10°C.

Steamed mussels, which had been washed and had their byssus filaments removed for storage show roughly the same reduction in quality as mussels which were not treated in this way. With regard to raw mussels the grades dropped more quickly for treated mussels than for untreated mussels.

Tables 2 A and 2 B present the number of storage days with overall grades above 7 and 5 respectively following dry storage at 3° and 10°C. For the storage series 7/3, the total impression grading is below 7 already at the first taste test. The reason for this is probably that these mussels had much food in (Page 42 their stomachs. This detracted from the appearance of the mussels and also affected the taste and smell.

Table 2 A). Number of storage days for a total impression grading of 7.

MONTH	January	March	April	June	August	October	November
WEEK	1	10	16	2[illegible]	34	40	46
3°, steamed	2.0	-	2.0	3.6	4.20	3.4	2.1
3°, raw	4.0	-	1.1	2.8	3.4	2.7	3.3
10°, steamed	3.0	-	1.8	2.1	3.0	2.4	2.2
10°, raw	2.9	-	3.3	2.7	2.0	1.9	2.2

The table shows that the storage time for a total impression grading of 7 for the 3° mussels varies between 2 and 4 days for steamed mussels, and between 1 and 4 days for raw mussels. For mussels stored at 10°C the storage time for both steamed and raw mussels ranges from 2 to 3 days.

These results indicate that the mussels, during dry storage, can withstand storage for 2 - 4 days at 3°C and 2 - 3 days at 10° without a significant reduction in quality.

The number of storage days which gave rise to a total impression grading of 5 is presented in Table 2 B.

Table 2 B). Number of storage days for a total impression grading of 5.

MONTH	January	March	April	June	August	October	November
WEEK	1	10	16	25	34	40	46
3°, steamed	16.0	12.0	10.1	9.4	11.3	11.5	13.5
3°, raw	14.6	12.0	8.1	8.0	9.9	10.8	12.0
10°, steamed	11.3	9.0	7.0	6.6	6.2	8.0	8.0
10°, raw	10.0	9.0	7.1	7.9	5.3	7.7	7.0

The mean value of number of storage days which provide a total impression grading of 5, for both raw and steamed mussels, is approximately 10 days at 3°C and 8 days at 10°C. After these storage periods the mussels are no longer acceptable for consumption. (Page 43)

Water loss, mantle water and mortality. The determination of water loss was carried out in order to determine whether the water content in the mussels could be used as an indicator of freshness, that is, how long could the mussels be stored dry.

The determination of mortality was done to investigate the mussel survivability in dry storage. Mussel survivability here means its ability to stay alive in dry storage. The number of storage days (storage at 3°C) which gave rise to a 5% mortality was used as a measurement of mussel survivability. The common mussel has adapted to life above water in order to survive low tides and will, therefore, during dry storage, stay closed in order to prevent loss of mantle water (mussel liquid). However, long periods above water will nonetheless gradually lead to a loss of water from the mantle cavity. This water loss was registered by measuring the reduction in total weight for each mussel sample and by measuring the amount of water (mantle water) in the mussels. The chapter on methods refers.

Figure 7 presents water loss as a reduction in total weight of all the storage series. For each of the storage series a comparison is made between mussels which are stored at 3°C and those stored at 10°C. A comparison between those mussels that were cleaned and which had their byssus filaments removed and those which were not given this treatment is made in the storage series 7/3. The figures indicate that the water loss is greater for mussels stored at 10°C than those mussels stored at 3°C. The water loss also increases when the mussels are washed and the byssus filaments removed.

Figure 8 shows how the amount of mantle water in the mussels changes (Page 44) with the storage. It also shows comparisons between storage at 3°C and storage at 10°C. As well, comparisons are made between washed and unwashed shells (storage series 7/3-83). The content of mantle water is reduced during storage. The difference between 3° and 10° is not significant; however, the figures indicate that the removal of byssus filaments increases the loss of mantle water during the first few days.

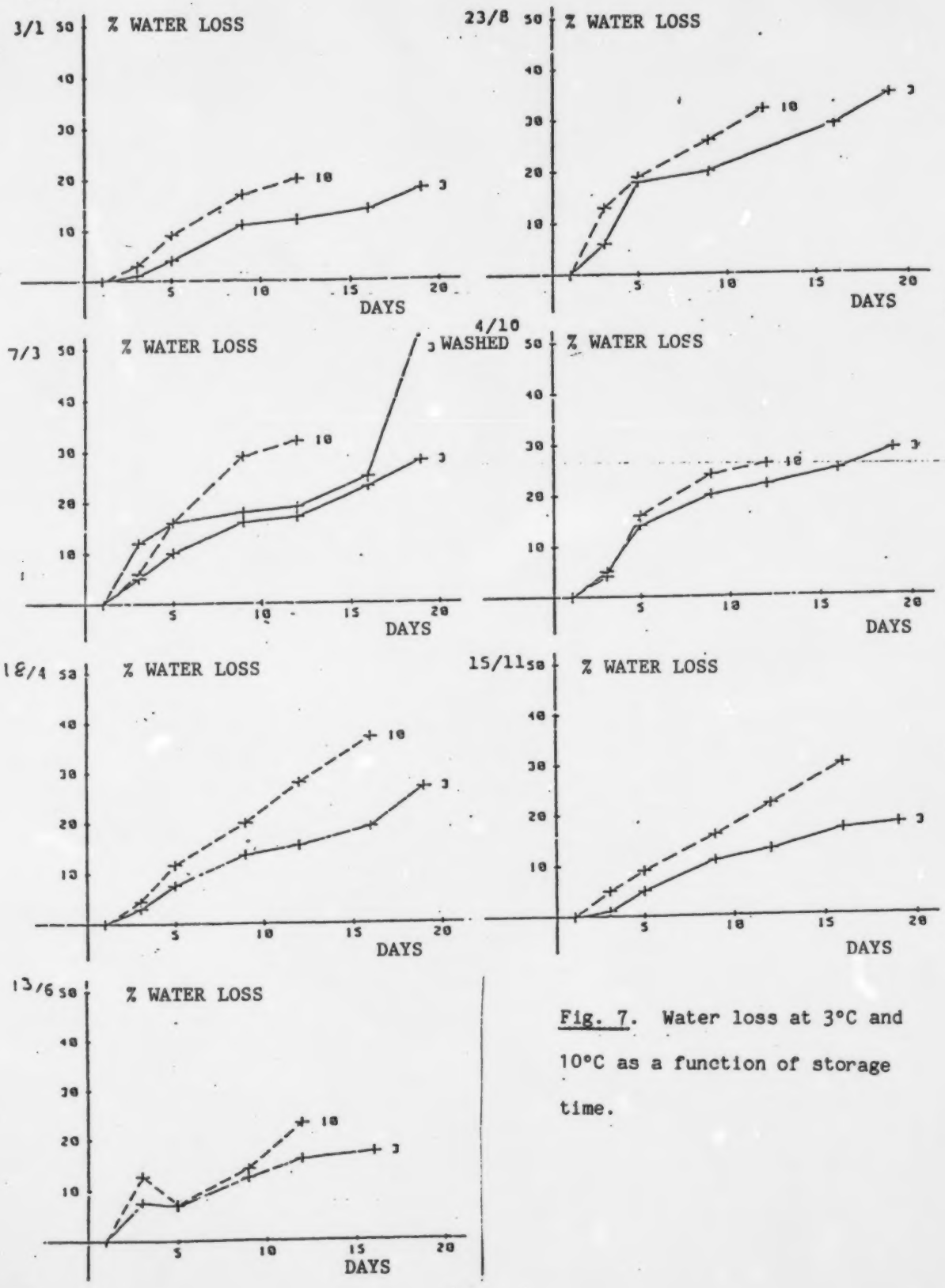

Fig. 7. Water loss at 3°C and 10°C as a function of storage time.

(Page 46)

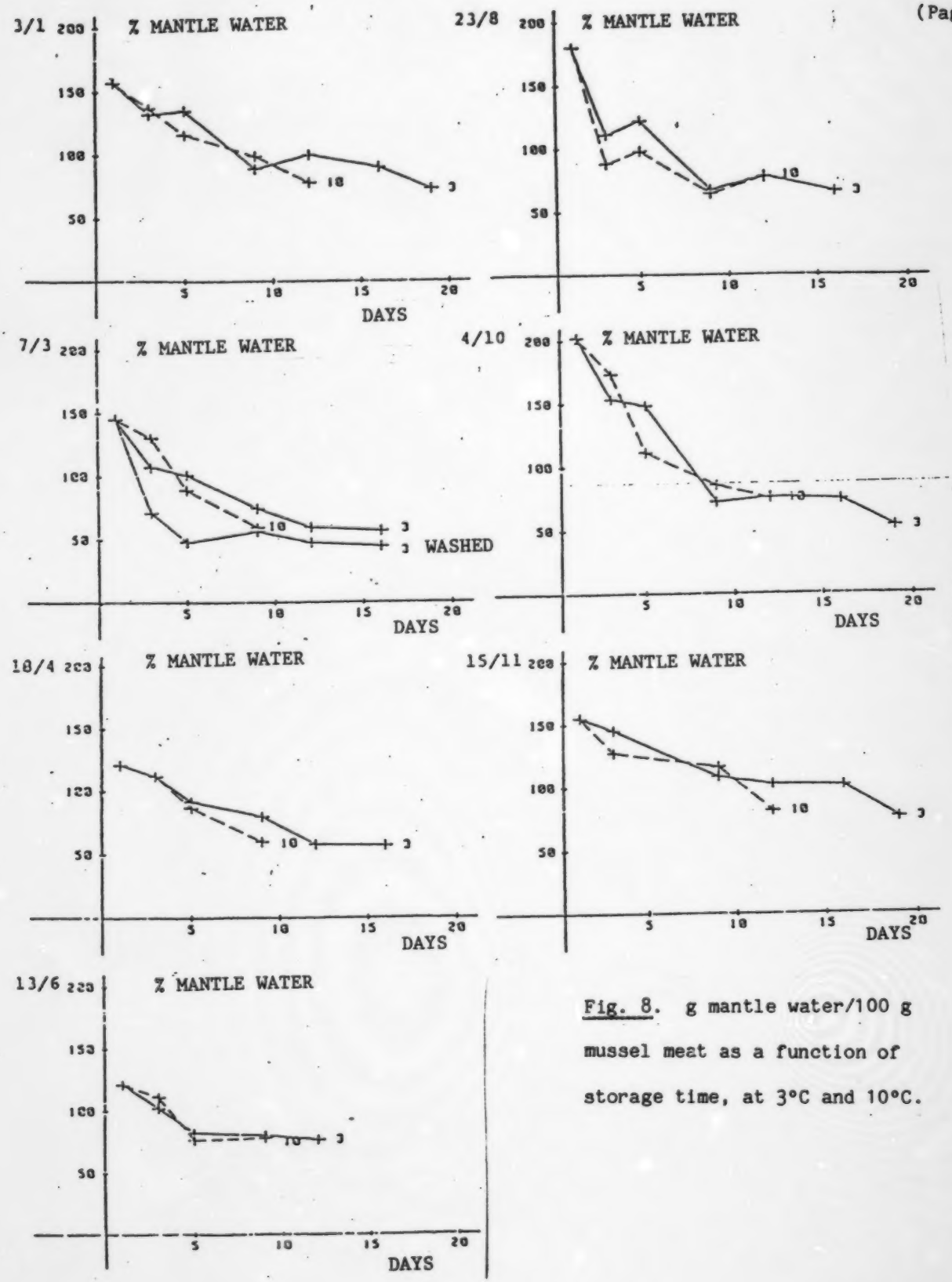

Fig. 8. g mantle water/100 g mussel meat as a function of storage time, at 3°C and 10°C.

The mantle water loss stabilizes between 50 and 70% of water (Page 47) content. This limit is quickly reached when the byssus filaments are removed.

On the basis of the results regarding water loss and mantle water, it can be concluded that one characteristic of freshness is that the mussels shall contain a fair amount of mantle water. An exact value for mantle water content is difficult to determine; however, a percentage content of mantle water between 100 and 150 would indicate very fresh mussels and thus low storage stress, while a percentage between 50 and 70 would indicate less freshness or high storage stress. When the mussels have had their byssus filament removed the mantle water content cannot be used as an indicator of freshness or storage stress.

The water content in the mussels is comparatively easy to determine during inspection of the mussels. Such determinations were made during the sensory tests and the test panel agreed that the amount of water was a comparatively good indication of storage stress.

The mussels must be alive during processing. The signs that this is the case are firmly closed mussels or mussels which close when the shell is struck. Although common mussels are adapted to live along beaches where they are exposed during low tide, long stays above water cause stress in the mussels. This particularly applies to mussels which have been bred in culture where they are continuously kept below the water and are therefore not adapted to life above the water. In such circumstances, the mussels suffer reduced access to nutrients and oxygen and there is a danger that they will dry out. The mussels will then stay closed to minimize the loss of mantle water and their metabolism will change so that the consumption of oxygen and energy is reduced. In this way the mussel can sustain life above water. However, after some time, depending on the mussel's resistance and the conditions to which it is exposed (temperature, moisture, etc.), the mussel will die. If, in addition, the mussel is exposed to (Page 48)

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rough handling during harvesting, transport, processing, etc., the situation will become still more stressful for the mussel.

Figure 9 shows the percentage of dead mussels as a function of storage time for all storage series at 3°C and 10°C. The mortality, as expected, is greater for mussels stored at 10°C than for those stored at 3°C.

Figure 10 presents the percentage of dead mussels following storage at 3°C as a function of the week number* with regard to storage periods of 1 - 19 days. The figure shows that the mortality rises above 0% only at the twelfth day of storage. The sensory tests showed that 3 - 4 days was the limit for good quality mussels in dry storage in a temperature of 2 - 5°C. Thus after a storage time of 3 - 4 days the mortality rate is 0% as shown in Figure 10.

Low or no mortality is therefore not an indication of freshness (short storage time) and high quality. Even though the mussels are able to stay alive for a long time in favourable storage conditions (temperature, moisture, etc.) the mussel may not be fresh although the mortality is low or zero. For instance, the shells from January have a mortality rate of 2% after 19 days (Figure 9). The quality reduction in such circumstances is clearly evident by bad smell and taste of the mussels caused by waste products from the mussel's own metabolism and from micro-organisms.

A high mussel mortality is, however, a sign of either that the mussels had a low resistance during harvesting, or that the storage and treatment stresses have been excessive.

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*Translator's Note:- the week number is a common measure of time in Scandinavia. Thus, week number 4 would be the fourth week of January.

(Page 49)

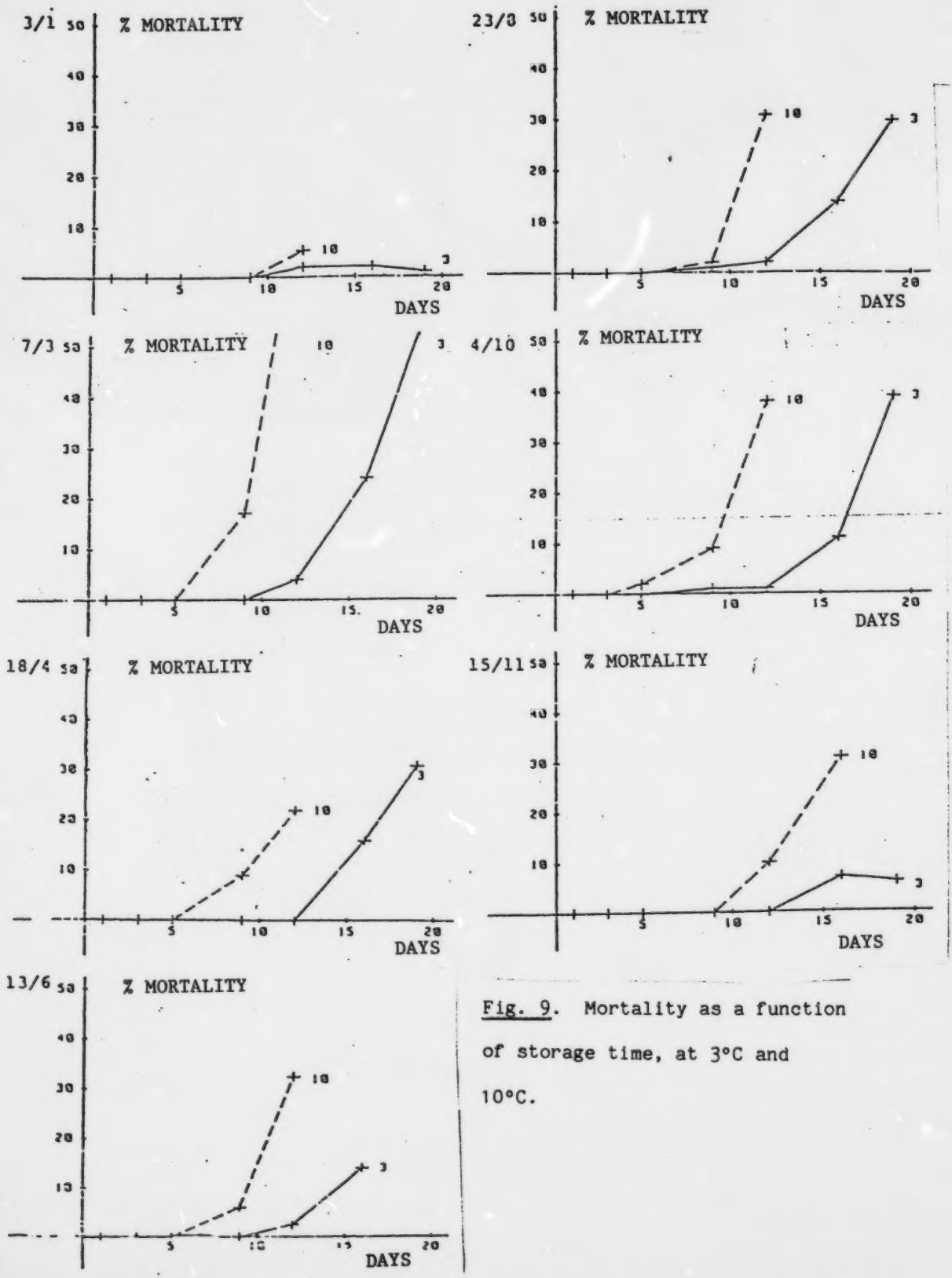
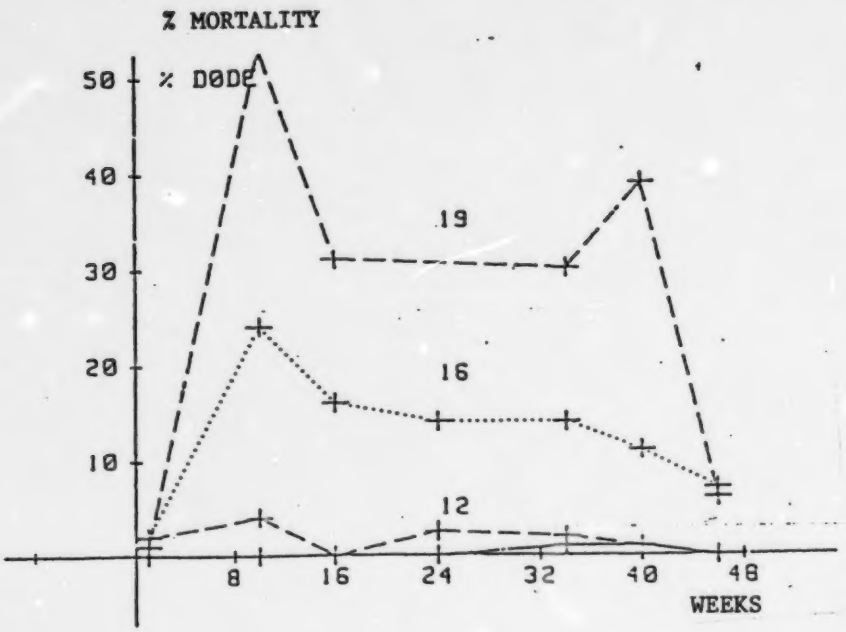


Fig. 9. Mortality as a function of storage time, at 3°C and 10°C.



(Page 50)

Fig. 10. Mortality during storage for 1, 3, 5, 9, 12, 16 and 19 days at 3°C as a function of week number.

These results show that the mortality in a batch of mussels should not exceed 0%. A mortality which exceeds 0% would indicate that something significant has occurred and that the quality has been reduced because: 1) the mussels at the outset had lower resistance and a short storage life, 2) the mussels were stored too long or in inappropriate conditions, or 3) the mussels were treated roughly during harvesting, transport or processing. It should be noted that dead mussels will also transfer a bad smell and taste to the live mussels. (Page 51)

Chemical parameters. These tests were carried out in order to establish parameters which change during storage and which can be used as objective indicators of storage stress and of quality. Emphasis was placed on finding parameters and analytic methods which were suitable for routine inspections.

In order to determine limit values of chemical parameters, the results were evaluated against the results from the sensory tests. During these evaluations an attempt was made to also consider the wide spread of the sensory

test results and the difficulties surrounding a reliable sensory quality assessment of the common mussel. As well, the comparatively limited test material was also borne in mind.

Since the common mussel produces NH_3 as waste matter and since bacteria also will produce NH_3, it was investigated whether the total volatile nitrogen in mussel flesh and mantle water increased during storage. Figures 11 A and 11 B show the content of total volatile nitrogen in raw and steamed mussel flesh from mussels stored at 3°C and 10°C. Figure 14 C shows the content of total volatile nitrogen in mantle water. Figure 15 shows the mean values for storage series.

(Page 52)

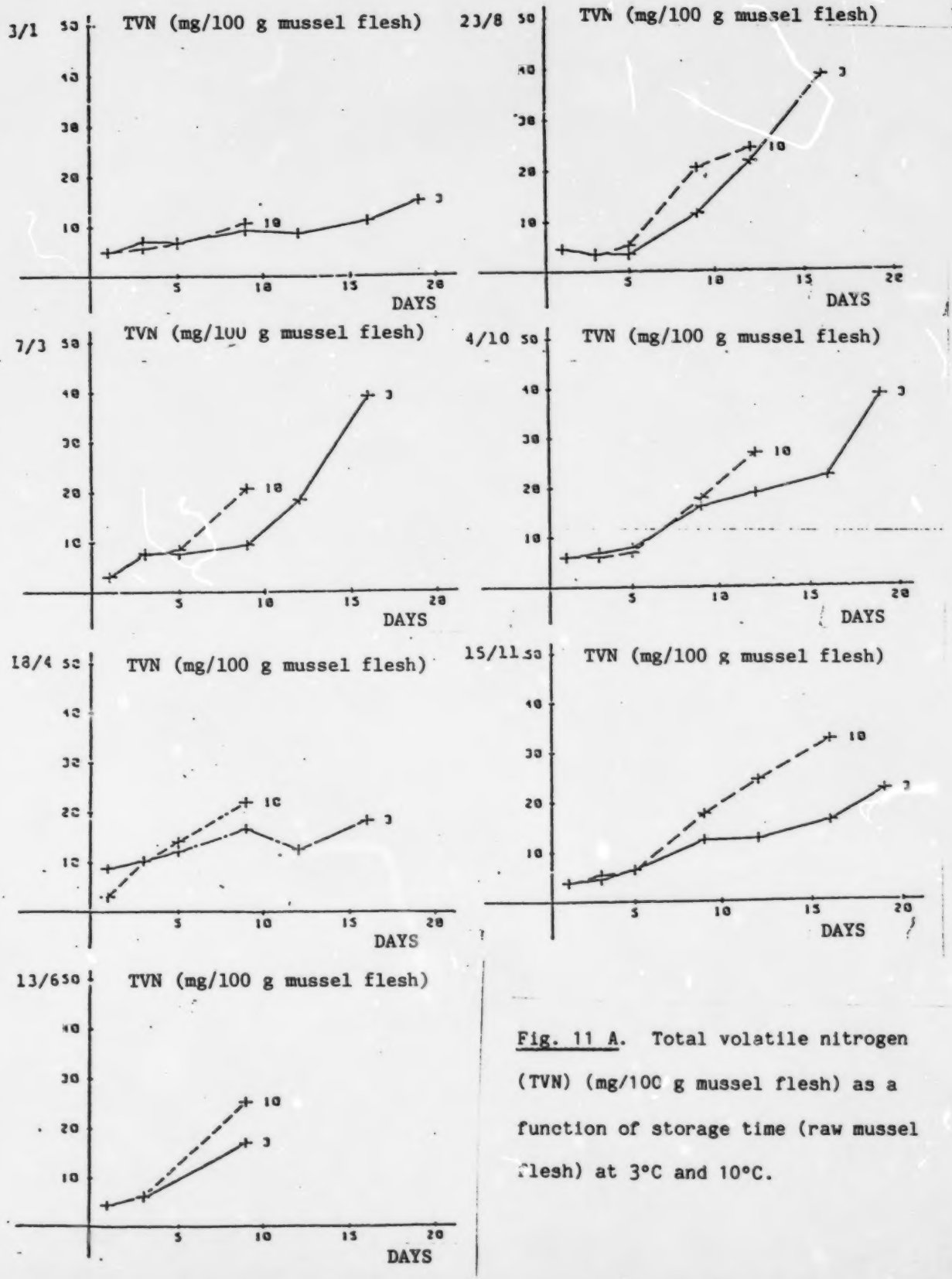


Fig. 11 A. Total volatile nitrogen (TVN) (mg/100 g mussel flesh) as a function of storage time (raw mussel flesh) at 3°C and 10°C.

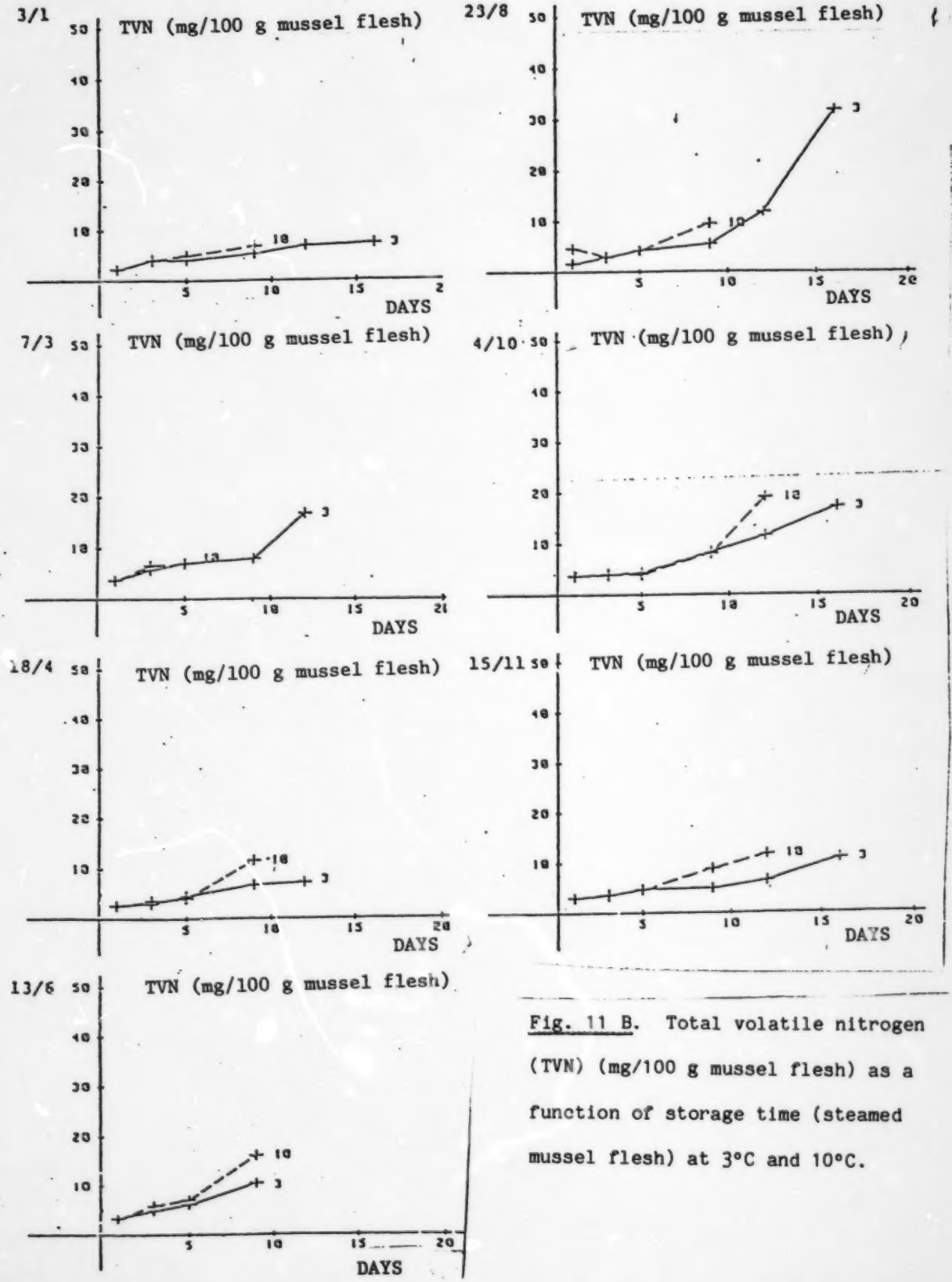


Fig. 11 B. Total volatile nitrogen (TVN) (mg/100 g mussel flesh) as a function of storage time (steamed mussel flesh) at 3°C and 10°C.

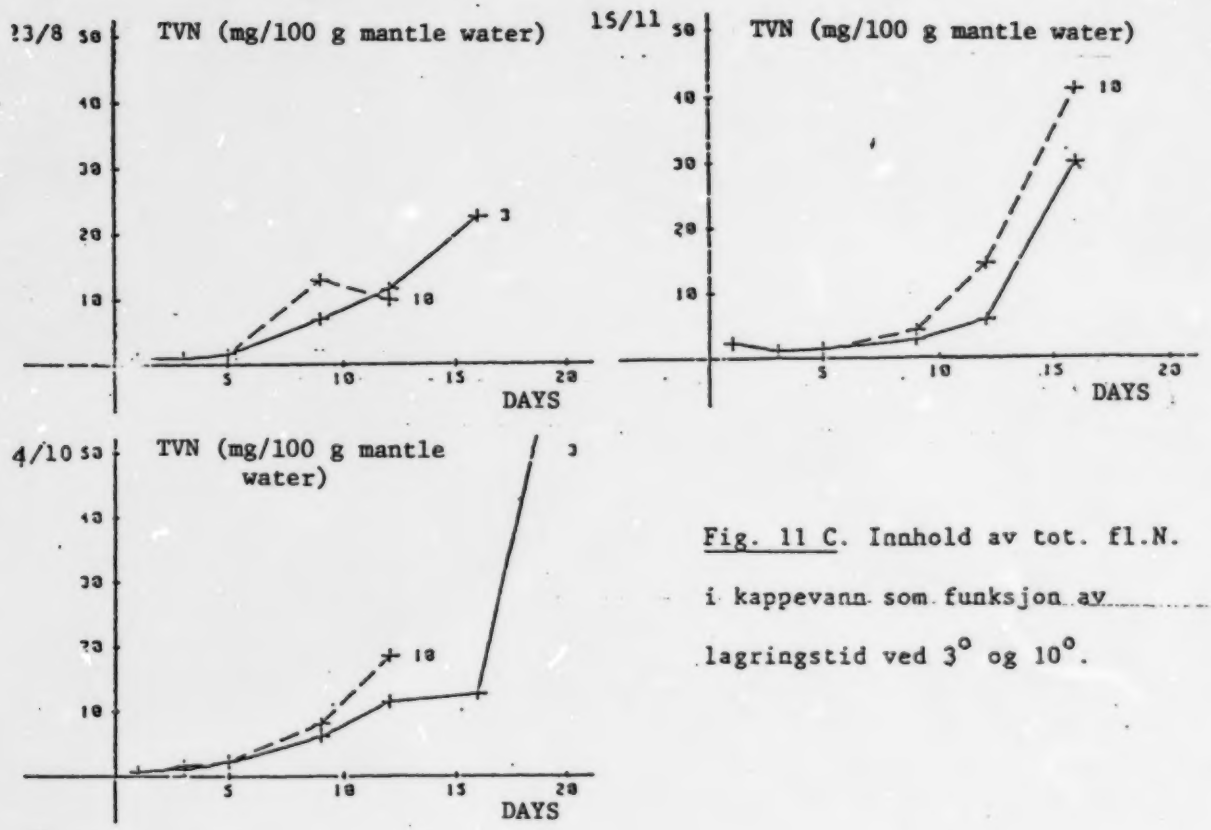


Fig. 11 C. Innhold av tot. fl.N. i kappevann som funksjon av lagringstid ved 3° og 10°.

Fig. 11 C. Total volatile nitrogen in mantle water as a function of storage time, at 3°C and 10°C.

The figures show that the total volatile nitrogen increases over storage time, both in mussel flesh and mantle water. With regard to mantle water, it appears that the increase begins only after some 5 days. The increase in TVN does not appear temperature dependent during the first 5 days. Thereafter the increase in TVN is greater in mussels stored at 10° than those stored at 3°C. The content of TVN is greater in raw mussels than in steamed mussels.

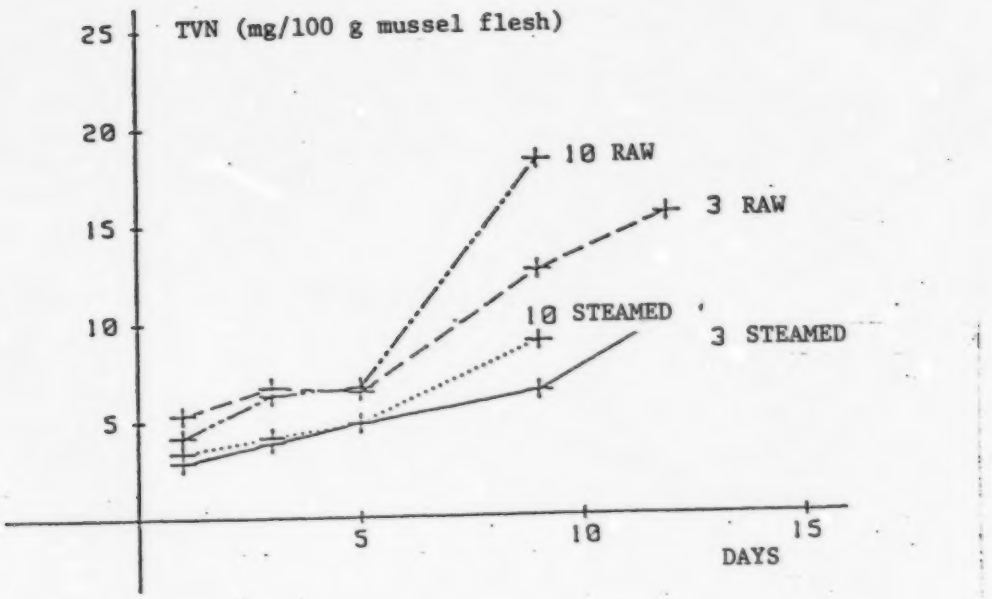


Fig. 12. Mean content of TVN (mg/100 g mussel flesh) in raw and streamed mussel flesh as a function of storage time at 3°C and 10°C.

TVN for the total impression grades of 7 and 5 were calculated for all storage series from the period August 1982 - June 1983 (Table 3).

Table 3. Content of TVN for total impression grades of 7 and 5.

STORAGE SERIES	TVN FOR TOTAL IMPRESSION GRADES 7 AND 5							
	RAW				STEAMED			
Temp	3°		10°		3°		10°	
GRADE	7	5	7	5	7	5	7	5
23/8	3.54	14.64	3.00	6.37	3.64	10.28	3.00	5.82
4/10	6.77	17.73	6.00	14.29	4.76	10.98	3.77	6.98
15/11	4.87	12.61	4.90	12.00	3.24	8.11	3.49	7.80
3/1	7.04	10.29	-5.70	11.50	3.22	7.40	4.10	7.50
7/3	3.00	18.40	3.03	21.00	3.02	16.70	3.01	7.50
18/4	9.30	15.92	10.88	18.40	3.02	7.00	3.15	8.96
13/6	5.78	17.50	6.06	22.55	4.50	10.50	4.86	10.66

TVN for total impression grades of 7 and 5 varies between the following values (standard deviation in percent is presented in parentheses). (Page 56)

Grade	7		5	
temp.	3	10	3	10
Raw	3.0-9.3 (40%)	3.03-11 (35%)	10.29-18.50 (18%)	6.37-22.55 (42%)
Steamed	3.02-4.76 (19%)	3.01-4.86 (17%)	7.0-10.98 (33%)	5.62-10.66 (23%)

On the basis of these results, and on the calculation of means of standard deviation, the following limit values are proposed for TVN (mg/100 g mussel flesh) in mussel flesh:

	Raw	Steamed
Good commercial quality	8 - 9 (10)	4 - 5
Not acceptable for consumption	20	10

The variations and percentage of standard deviation for TVN at total impression grades of 5 and 7 are large and in most instances larger for raw mussels than for steamed mussels. Some of this difference may be caused by variations in handling and storage stress occuring during preparation of the samples. Such differences would probably be more evident in raw mussels than in streamed mussels, since raw mussels have their own bacteria and enzymes intact, while these, to a larger or smaller extent, are destroyed by steaming.

The difference can also be explained by the total impression being more influenced by other parameters (for instance, other chemical compounds which develop in the mussels) than by the TVN. As well, there may be better correlation between these and other compounds and the content of nitrogen in steamed mussels than in raw mussels.

The standard deviation values show that it is probable that the (Page 57) indicated limit values for TVN are more uncertain for raw mussels than for steamed mussels. Thus, it appears that inspection of TVN is best done on steamed mussel flesh. The proposed limit values should, however, be studied further on the basis of more data, for instance, by testing from various sites.

Figure 13 presents the relationship between total impression and TVN based on mean values for all storage series.

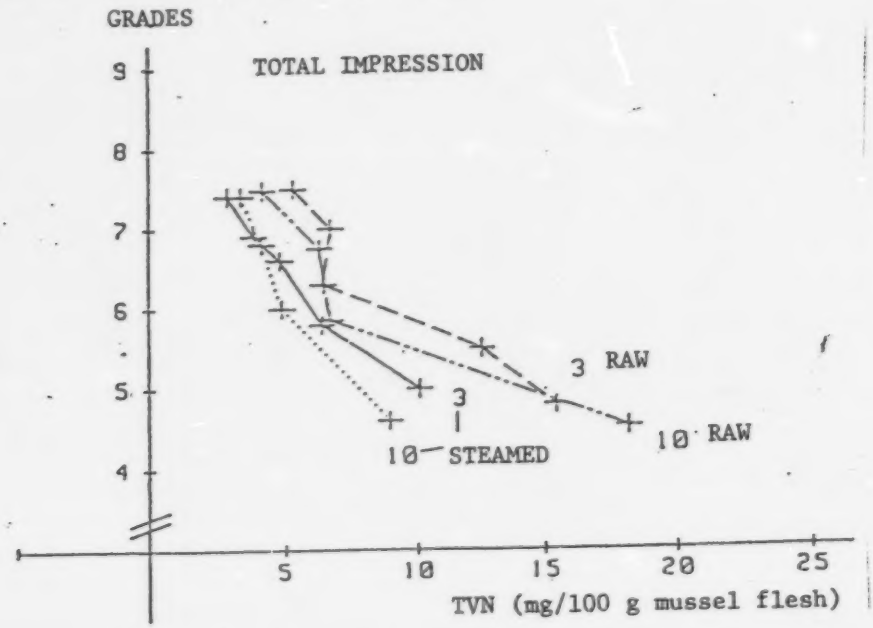


Fig. 13. Relationship between TVN and grades for total impression, based on the mean of all storage series. (Page 58)

Table 3 shows that the TVN for total impression grades of 5 in some of the storage series is less for the 10° mussels than for the 3° mussels. The same tendency is evident in Figure 13 which presents the mean of all storage series. This may also be an indication of reduced quality recorded as bad smell and taste. It may be related to the presence of metabolites, other than NH_3. If one could establish by simple means the existence of such metabolites and if they increased at a specific and reproduceable amount during storage then this could an excellent quality index of storage stress.

Whether the pH varied with storage and could be used as an index for storage tests was also investigated. Figure 14 shows the pH in raw and steamed mussels as a function of storage time, at 3° and 10°C for all these storage series. It became evident that an increase in pH is approximately the same for both storage temperatures. As well, it was found that pH was less in raw mussels than in steamed mussels. Should one wish to determine whether mussel flesh is raw or steamed, then this could be done by measuring the pH. However, it is probably better to establish this by visual inspection. Table 4 shows the pH values for total impression grades 7 and 5.

Table 4. pH for total impression grade of 7 and 5.

STORAGE SERIES	pH							
	RAW				STEAMED			
TEMPERATURE	3°		10°		3°		10°	
GRADE	7	5	7	5	7	5	7	5
22/8		6.51		6.49		7.06		6.72
4/10				6.60	6.95		6.85	7.07
14/11	6.43	6.51	6.38	6.50	6.82			7.0
2/1	6.30		6.26	6.41	6.14	6.94	6.82	7.02
7/3		6.44				7.02		
17/4								
13/6	6.33	6.57	6.34	6.42	6.71		6.70	6.86

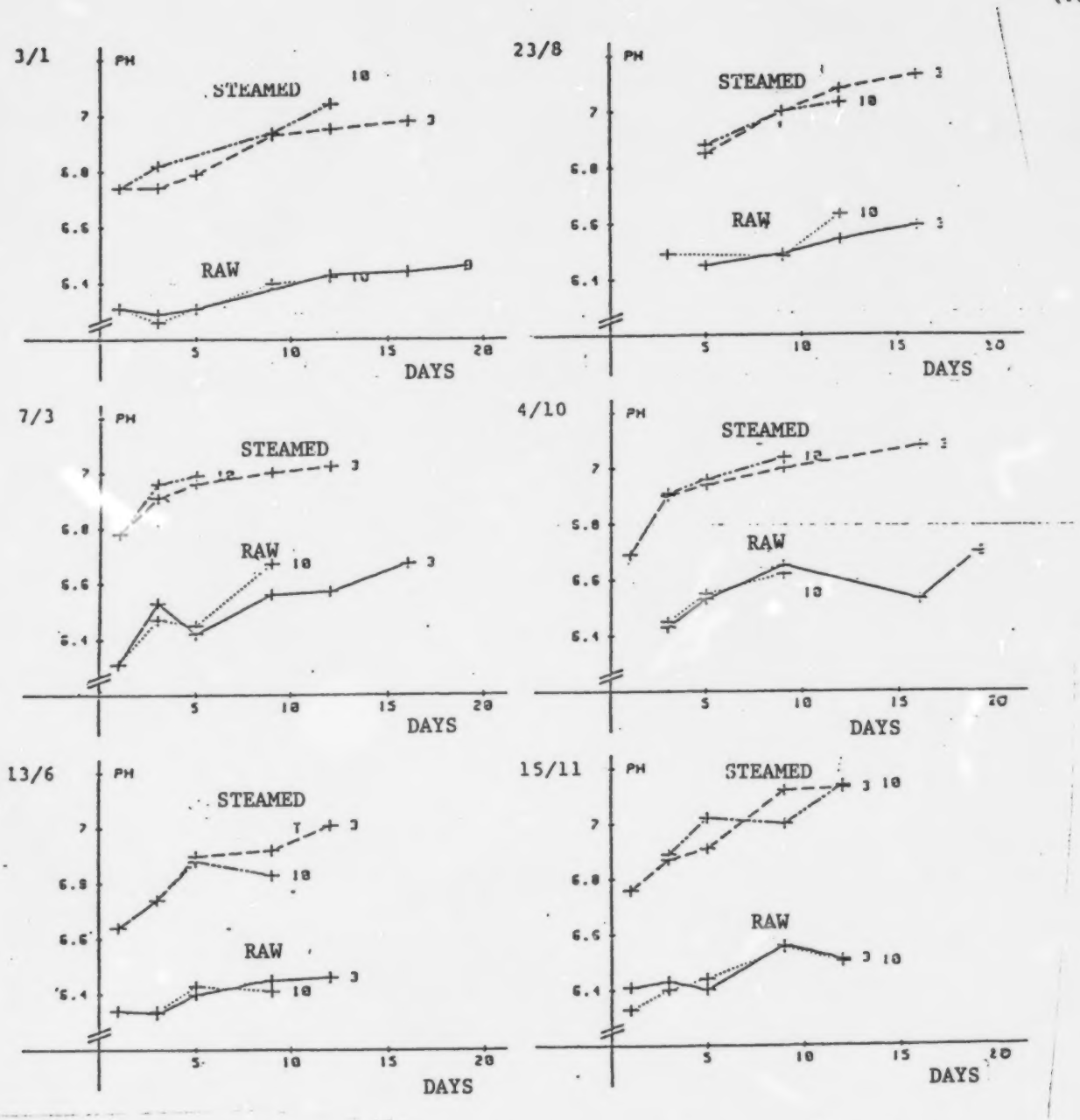


Fig. 14. pH in steamed and raw mussels as a function of storage time, at 3°C and 10°C.

pH for total impression grades of 7 and 5 varies between the following limits: (Page 60)

Total Impression	7		5	
Temperature	3°	10°	3°	10°
Raw	6.33-6.43	6.26-6.34	6.44-6.57	6.41-6.60
Steamed	6.71-6.95	6.70-6.85	6.94-7.02	6.86-7.07

On the basis of these results, and based on calculation of mean values and standard deviations, the following limit values are proposed:

	Raw	Steamed
Good Commercial Product	6.4	6.9
Not acceptable for consumption	6.6	7.1

These results are based on very limited tests and should be followed up by further studies if pH is to be used as a measurement of freshness.

Figure 15 presents the relationship between pH and total impression, based on mean values.

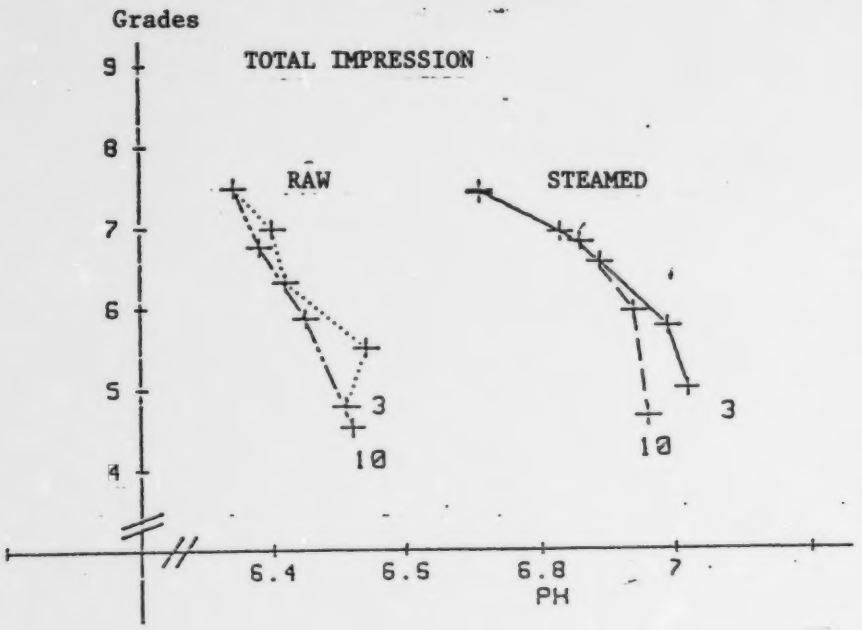


Fig. 15. Relationship between total impression and pH for raw and steamed mussel flesh, stored at 3°C and 10°C (mean for all storage series).

It was investigated whether during the storage of mussels it was possible to detect an increase in the content of amino acids by measuring the increase of ninhydrin reactive substances (NRS) in the mantle water and mussel flesh. Figures 16 A and 16 B show the results of these determinations.

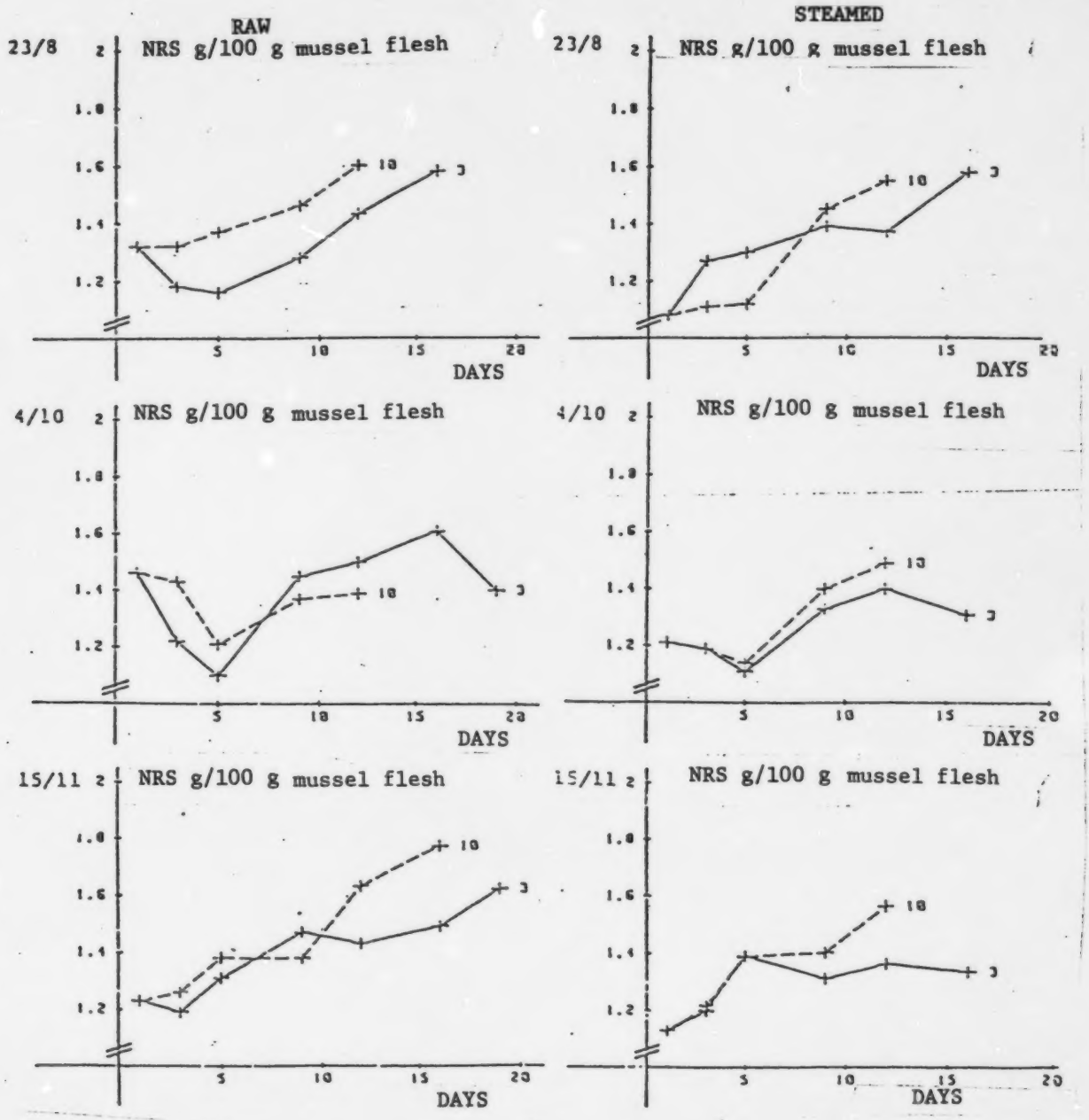


Fig. 16 A. NRS content in protein free extract (g/100 g mussel flesh) in raw and steamed mussels as a function of storage time, at 3°C and 10°C.

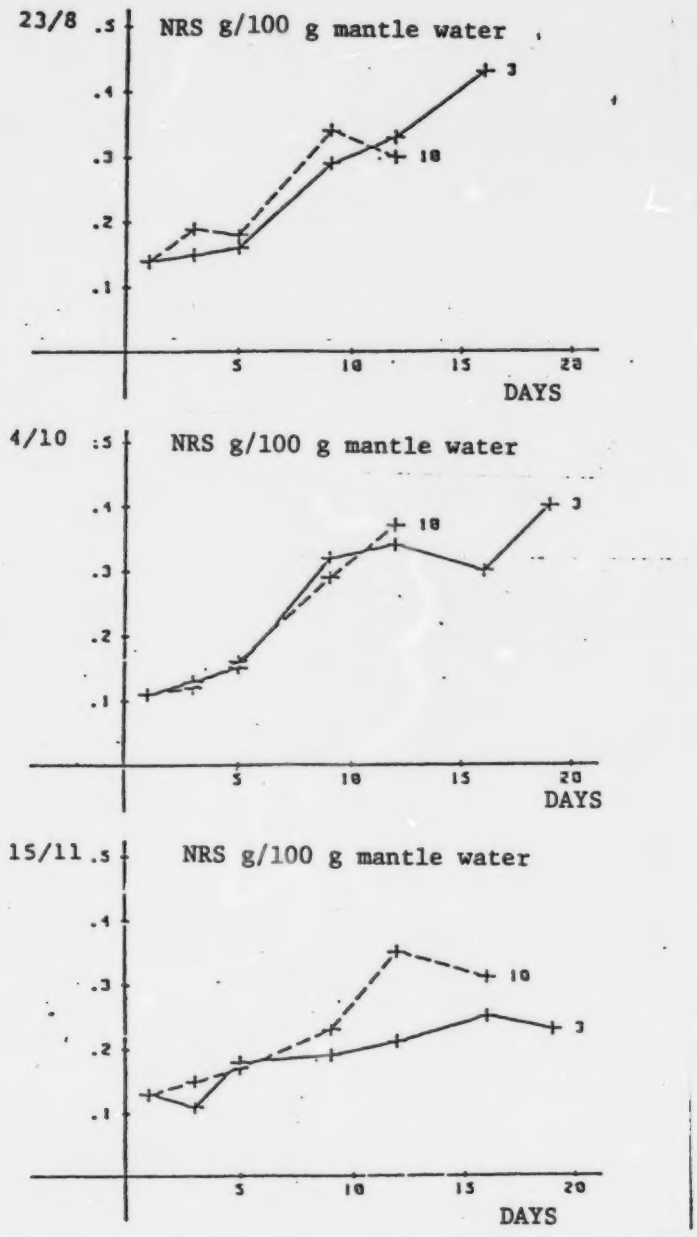


Fig. 16 B. NRS content (g/100 g mussel flesh) in mantle water as a function of storage time, at 3°C and 10°C.

Most of the results show that the content of NRS in the mussel flesh is higher at the end of the storage period than at the beginning. The development of NRS in mussel flesh during storage is, however, not so clear that limit values can be determined for this parameter. In particular this applies to the earlier studies of storage during which the NRS in some series drops during storage. The content of NRS in mussel flesh is therefore not suitable as an indicator for storage stress in the early stages. It is possible that determination of NRS could be used for establishing storage stresses which exceed acceptable limits. However, this is not very relevant since this kind of stress can be much more easily determined by sensory tests. (Page 64)

The increase in NRS content in mantle water is more clear. This increase is in part an expression of the reduction in content of the mantle water in the mussel since the development of NRS in the mussel will lead to an increasing concentration with reduced amounts of mantle water. Nonetheless, the NRS in the mantle water can be a measurement of storage stress. In particular it would be suitable for inspection of raw mussels. On the basis of the results presented in Figure 19 B, it appears that mussels with less than 0.15 g NRS/100 g of mantle water are of a quality which can be considered a good commercial product. A content of 0.2 - 0.3 g NRS/100 g of mantle water indicates that the mussels are no longer of an acceptable quality. With regard to the detection of excessive storage stresses, these can more simply be determined by sensory tests or by measuring the amount of mantle water. As well, with regard to NRS, further studies are required before it is used as a determinant.

Extracts from the common muscle hinge were analysed by gaschromatography/mass-spectrometry as a function of storage time. No systematic changes could be detected in the volatile components. The reason for this may be that any changes are very small and not detected during the analysis of volatile compounds, since the shells are alive during the storage period. (Page 65)

Bacteriological tests. Figure 17 shows the results from the bacteriological test.

The total number of live bacteria increased with storage time. The increase is slightly larger for mussels stored at 10°C than for those stored at 3°C. The mussels which were cleaned and had their byssus filaments removed showed the same increase as shells which were not treated in this manner. Following storage for 3 - 4 days the total number of live bacteria in the mussels stored at 3°C varies between 5,000 and 50,000 in the various storage series. On this basis it appears that a total number of live bacteria of 50,000/g of mussel flesh would be a suitable upper limit for a good commercial product. Mussels which exceed 100,000 cannot be considered suitable for consumption.

Table 5 presents the content of coliform bacteria, fecal coliform bacteria and fecal streptococci. The content of coliform and fecal coliform bacteria varies with the seasons. In some of the series the values were above those indicated by Codex.

Table 5. Content of coliform, fecal coliform and fecal streptococci in raw mussel flesh.

Storage series Start of the week	1	10	16	24	34	40	46
Coliform	4	0	0	9	0	0	3
Fecal coliform	4	0	0	9	0	0	0
Fecal Streptococci	0	0	0	0	0	0	0

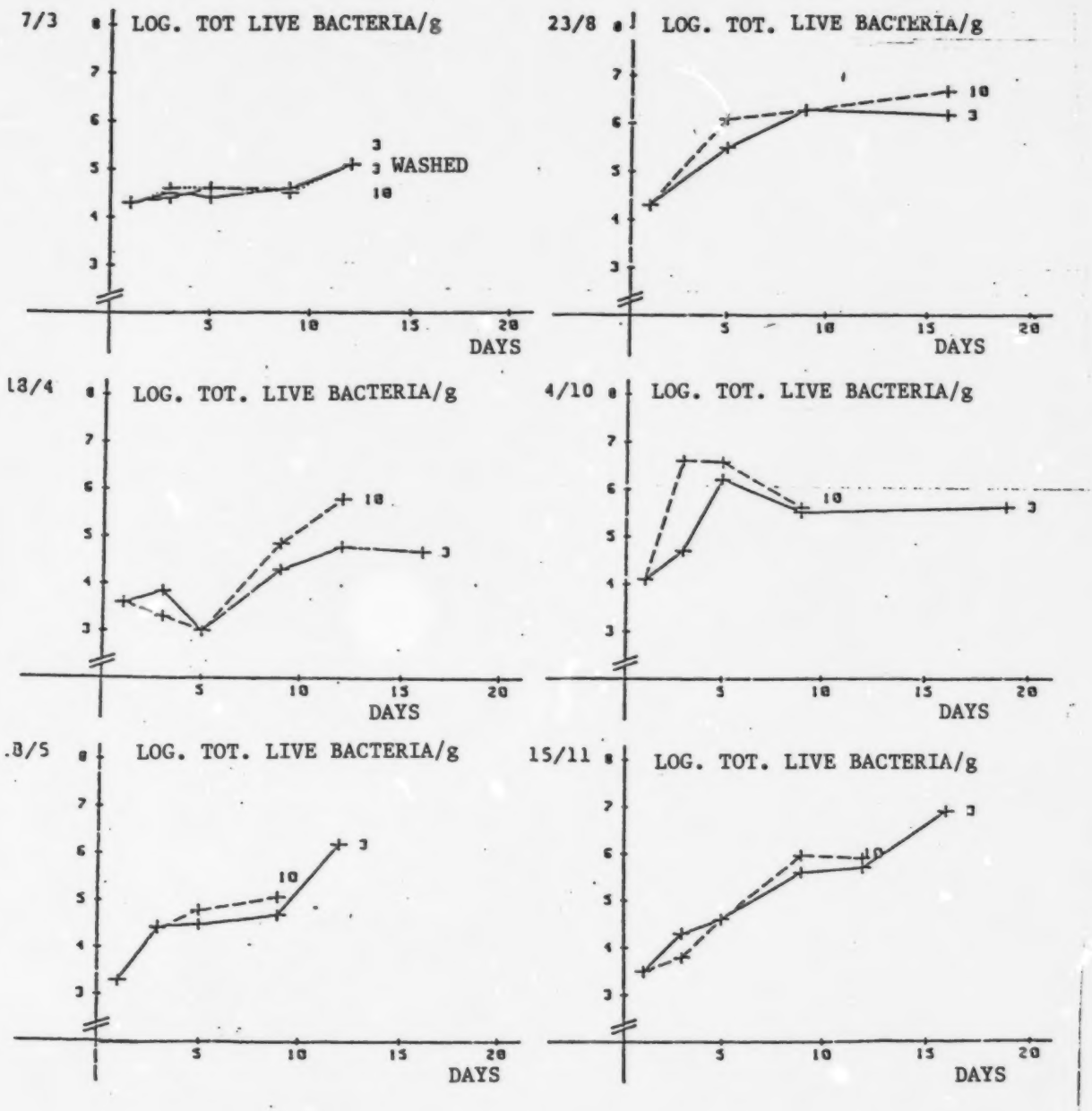


Fig. 17. Total number of live bacteria in raw mussel flesh as a function of storage time, at 3°C and 10°C.

Seasonal variations. To establish which season of the year is most (Page 67) suited for harvesting of the common mussel, the mussel quality and physiological condition as a function of season was investigated by carrying out the following analysis at the beginning of each storage series:

food content

fat

protein

carbohydrates

dry matter

metals (in 4 of the series)

total volatile nitrogen

pH

bacteria count

% mantle water and % water loss

sensory quality (total impression)

sensory freshness in dry storage (number of storage days at 3°C with a total impression grade of 5)

survivability in dry storage (number of storage days at 3°C with 5% mortality

The results from the season variation studies are presented in Figures 18 - 27 and Table 6.

(Page 68)

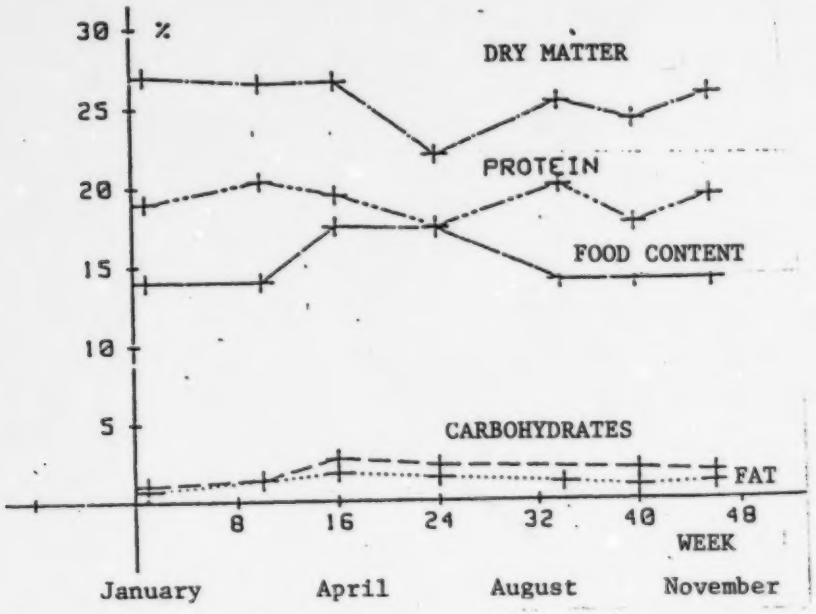


Fig. 18. Food content, dry matter, protein, carbohydrates and fat content in fresh common mussels as a function of season.

(Page 69)

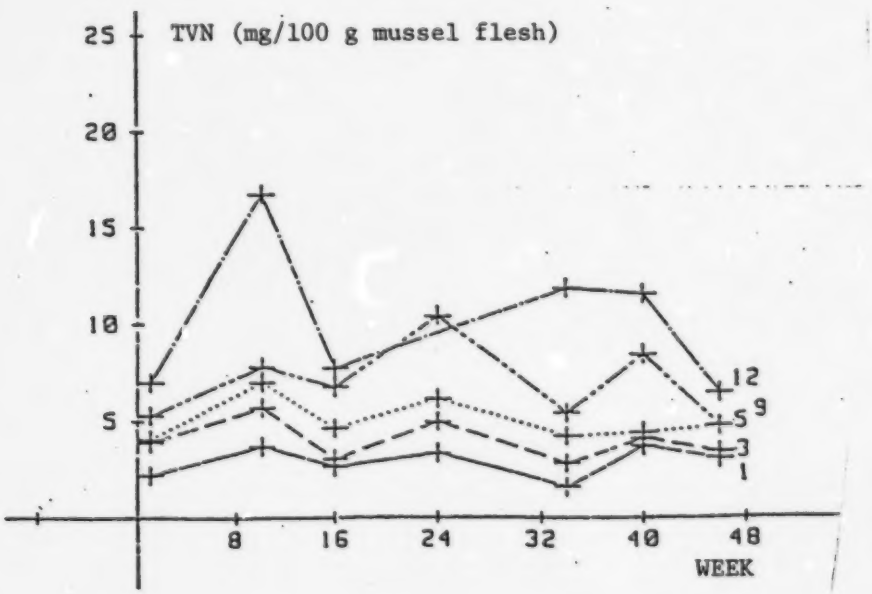


Fig. 19. Content of TVN (mg/100 g mussel flesh) in steamed mussel flesh as a function of season, stored for 1, 3, 5, 9 and 12 days at 3°C.

(Page 70)

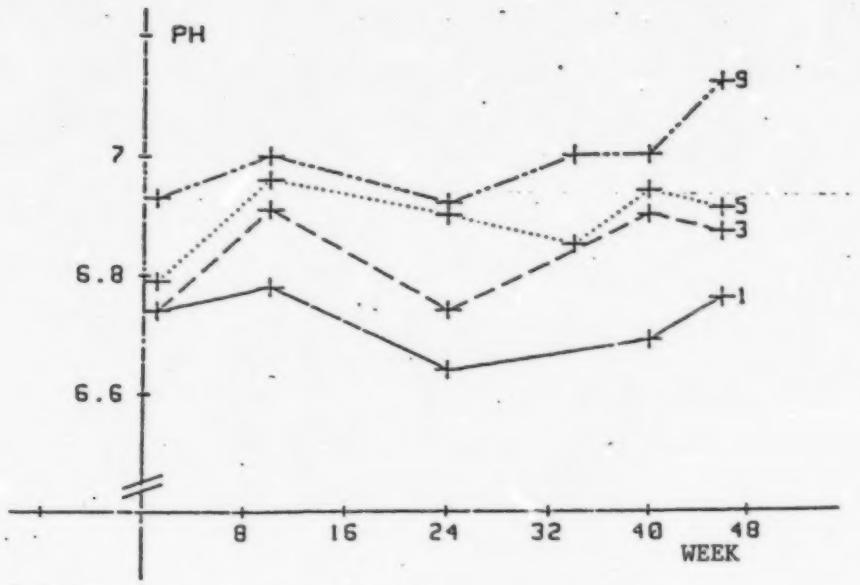
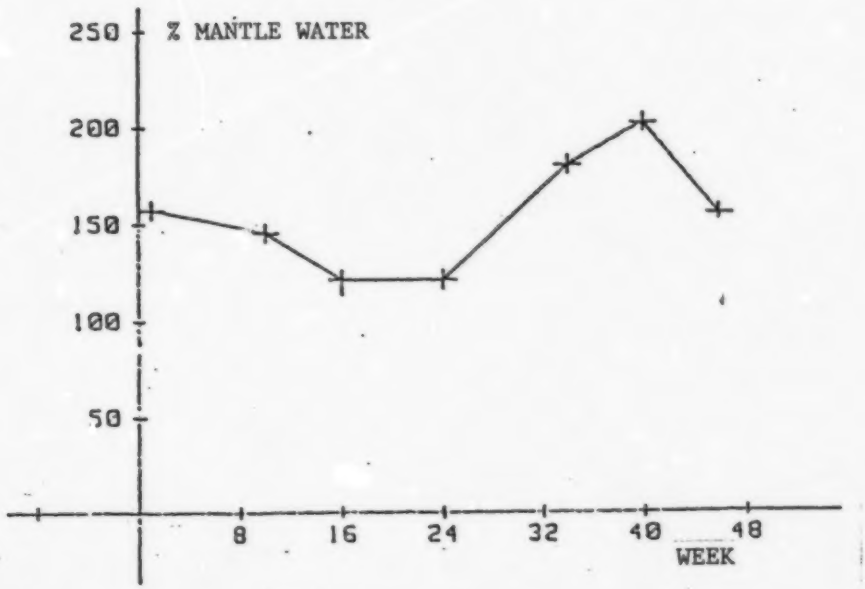


Fig. 20. pH in steamed mussel flesh as a function of season, stored for 1, 3, 5, 9 days at 3°C.

A)

(Page 71)



B)

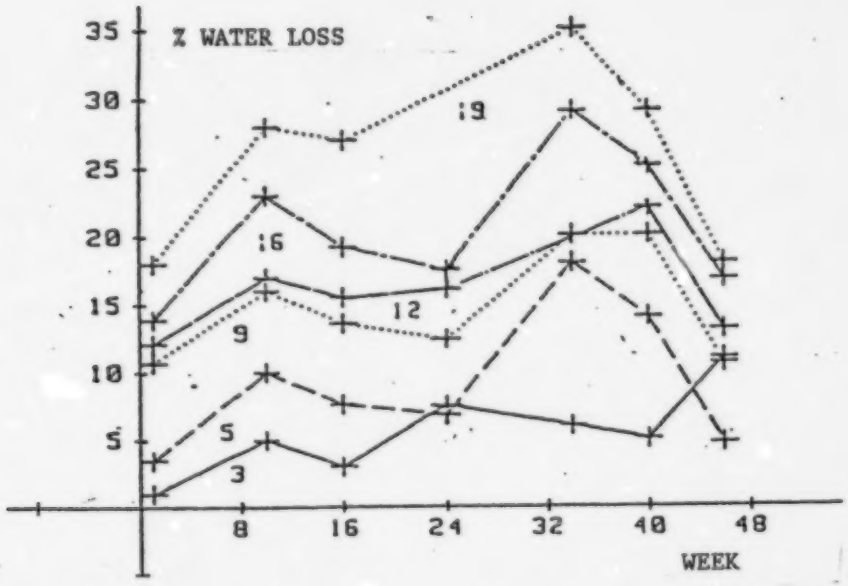


Fig. 21 A). Mantle water in fresh mussels as a function of season.

B). Water lost as a function of season following storage for 1, 3, 5, 9, 12, 16, 19 days at 3°C.

GRADES

(Page 72)

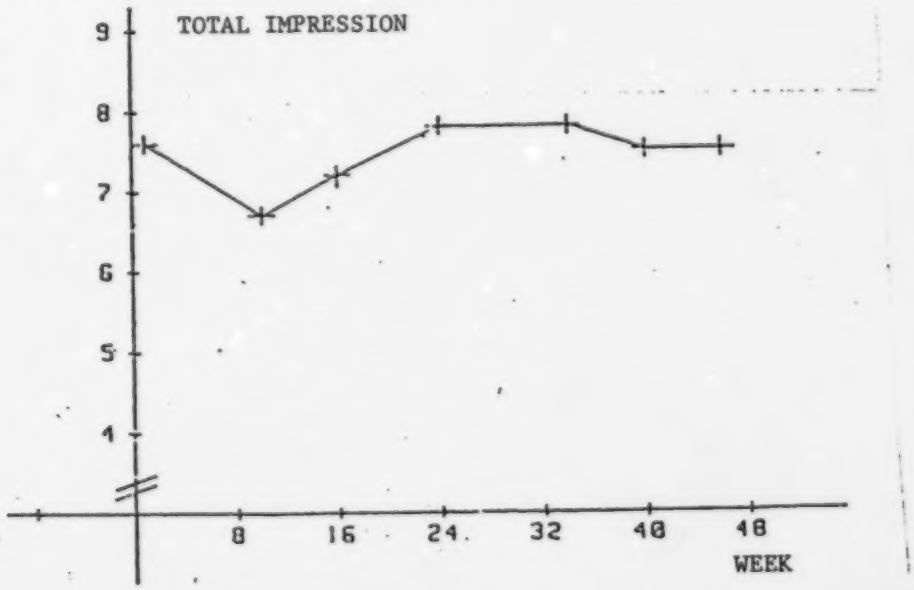


Fig. 22. Grades for total impression of fresh, steamed mussel flesh as a function of season.

(Page 73)

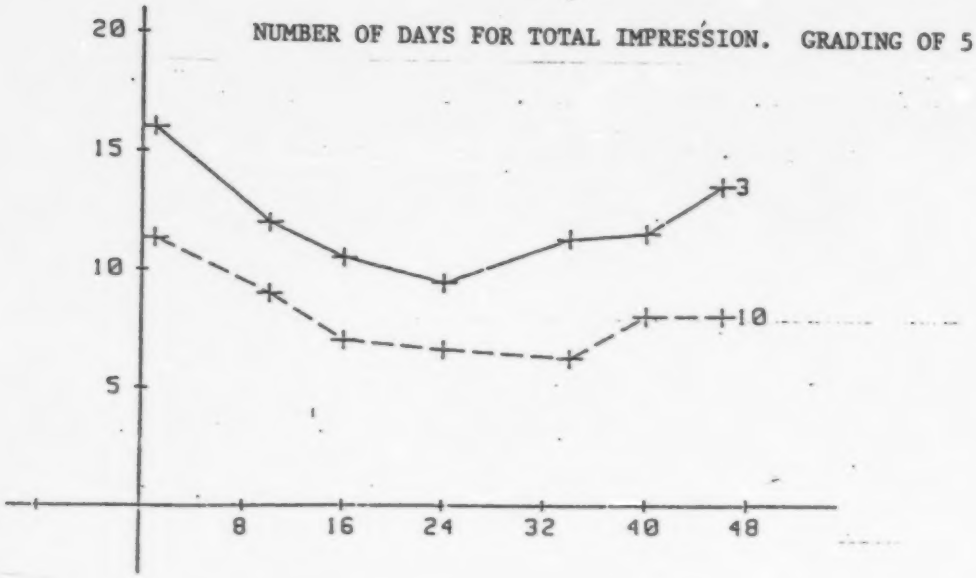


Fig. 23. Sensory freshness for mussels stored at 3°C and 10°C (measured on steamed mussels as storage days for a total impression grading of 5) as a function of season.

(Page 74)

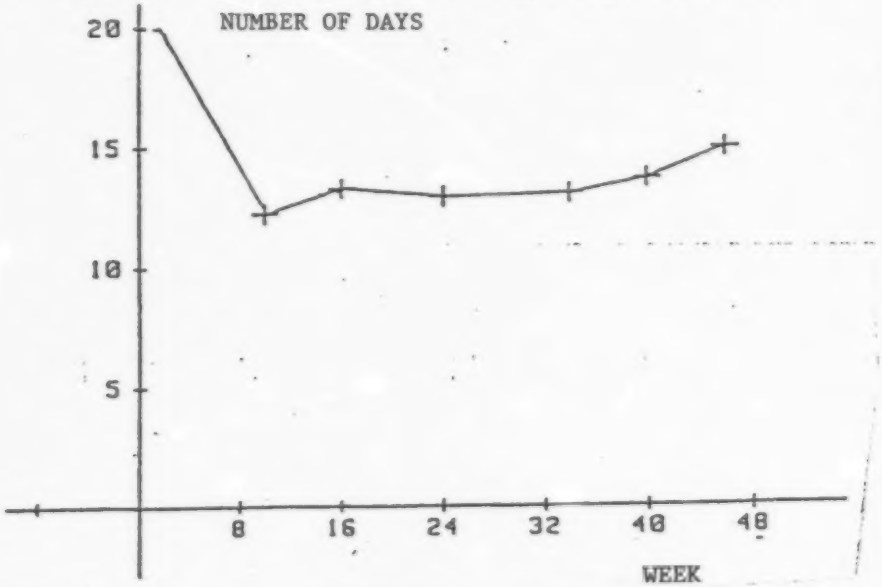


Fig. 24. Survivability (measured as number of storage days for 5% mortality) as a function of season, for mussels stored at 3°C.

(Page 75)

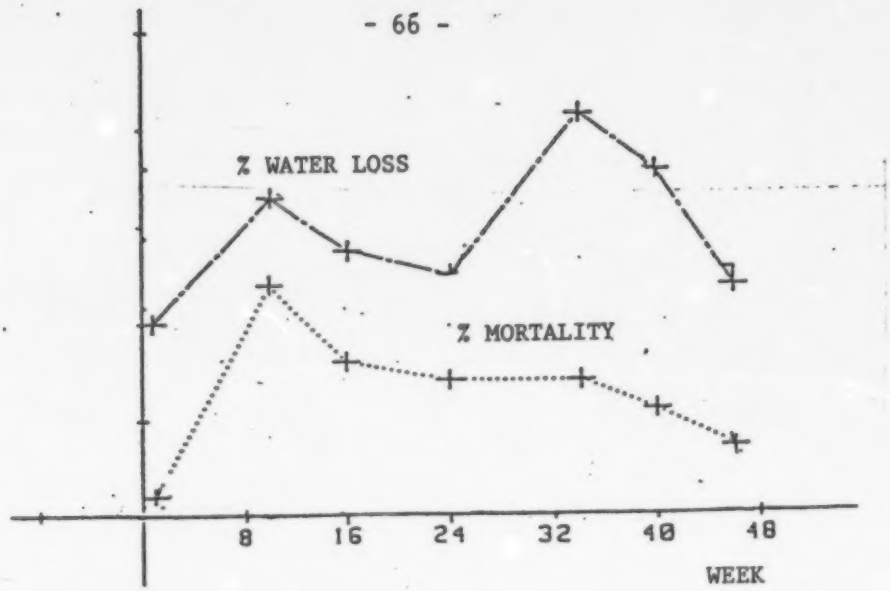


Fig. 25. Comparison between percentage water loss and percentage mortality after 16 days, as a function of season.

(Page 76)

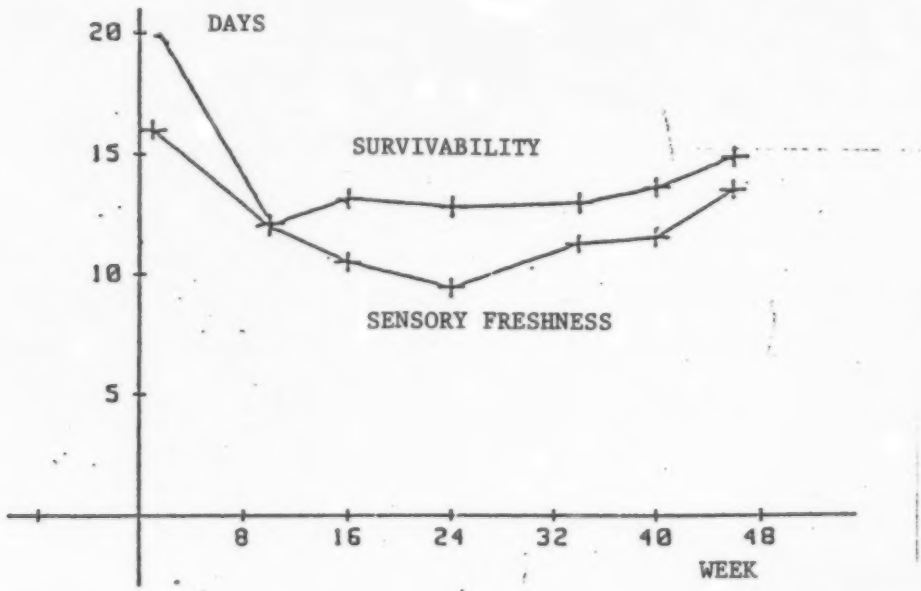


Fig. 26. Comparison between season variations in sensory freshness and survivability.

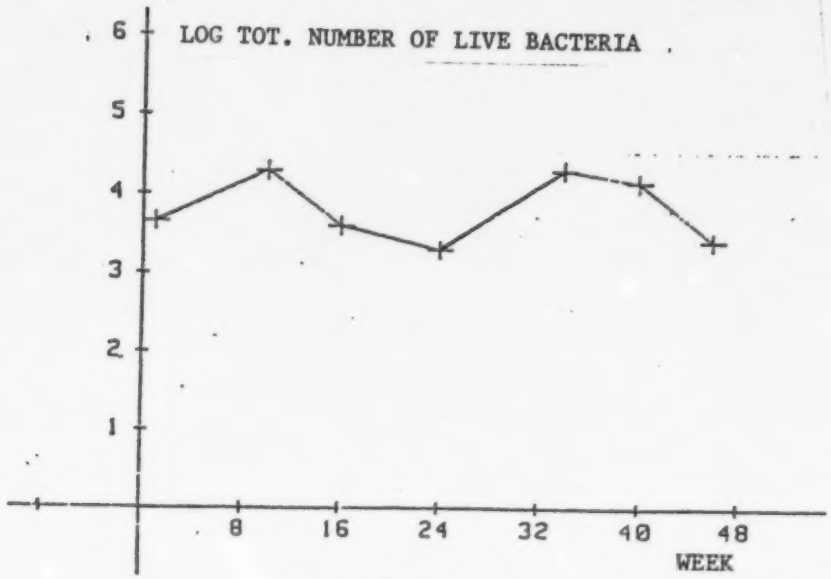


Fig. 27. Total number of live bacteria in fresh, raw mussels as a function of season (3°).

Table 6. Metal content

Metal content in common mussels from Hindenes. The samples were taken at various times of the year. The values are presented in mg/kg of fresh weight.

Date	Treatment	Dry Matter g kg^{-1}	Mg	Ca	Cu	Zn	As	Se	Cd	Pb	Hg
15.11.82	Boiled	237	1040	670	1.9	37	2.6	0.82	0.33	2.7	0.04
3.1.83	Frozen	144	1160	650	1.7	23	1.7	0.42	0.21	1.3	0.02
7.3.83	"	130	1050	680	1.2	19	2.6	0.58	0.30	1.3	0.01
1.6.83	"	109	731	930	0.85	12	0.75	0.23	0.13	0.61	0.01

Since this study was based on comparatively limited sample material (Page 79) and only concerned one season and one location, the representativeness of the data may be in question, particularly whether they provide a correct picture for the longer term and for all of the country. Nonetheless, the results provide some indications of the changes affecting the common mussel during a year. It is probable that these changes may occur earlier or later in one year compared with another and they may also vary depending on the part of the country as well as the growth conditions of the mussels.

The food content in the mussels (Figure 18) is highest in April - June before spawning takes place. A high food content in the spring is probably related to the availability of nutrients and the high temperature, and the fact that the mussels during this period are forming sexual cells. During summer and autumn, after the spawning has been terminated, the food content is comparatively low. It is also low during the winter because of nutrient and temperature conditions which do not allow the mussel to recuperate after the spawning.

Figure 18 also shows variations in the content of protein, fat and carbohydrates during the year. It appears that the food content and carbohydrates develop in parallel, while dry matter and protein also seem to follow each other during the year. However, the material from the study is too limited for any conclusions to be drawn from these results.

The sensory quality of fresh (non-stored) mussels is considered to be lowest in March - April (Figure 22). The sensory quality results for fresh mussels are considered quite unreliable because of the problems experienced in determining the quality of mussels when comparing one storage series with another. The mussels which were used in the study also had a very low food content. For these reasons no conclusions have been drawn with regard to (Page 80) variations in sensory quality during the year.

Sensory freshness is best in January (Figure 23). It is worst from April - August and improves from August to January.

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Seasonal variations in sensory freshness may depend on several conditions. When the mussels are stored dry they are prevented from disposing of metabolic waste by means of mantle water circulation. When the content of these waste products in the mussel flesh increases, the mussels begin to smell and taste badly. This condition may even be aggravated during those periods of the year when the mussel water content is low and/or there is a larger water loss from the mantle cavities (see the following).

During periods of high temperature and a good nutritional supply the mussel physiological activity increases. If they are placed in dry storage in these circumstances, the mussels may have difficulty in adjusting. This may particularly apply to bred mussels which are continually kept in the water and which are therefore not used to adapting to dry circumstances, such as low tide. Intense physiological activity leads to a high rate of metabolic activity in the mussels, which in turn leads to more rapid accumulation of waste products in the mussel flesh. The sensory freshness will probably also be influenced by seasonal variations in the temperature to which the mussels are exposed during harvest and transport to the laboratory. The bacteria which break down the mussels will develop better in warm seasons and transformation of the stomach content can lead to a more rapid reduction in sensory quality during periods with high stomach content.

The content of mantle water in the mussels varies throughout the year (Fig. 21 A). It is highest in August - October and lowest in April - June. This variation is related to spawning and food content. The low content of mantle water during April - June may be explained by the high food content of the mussels during this period, while the high content of the mantle water in the autumn may be explained by a low food content. (Page 81)

Figure 21 B shows the water loss as a function of the week number. The figures show that the water loss for a given storage period varies throughout the year. The storage series in August showed a greater loss of water throughout the whole series (with the exception of storage day no. 5) than the other series. November and January show the lowest values (with the exception of November with regard to storage day no. 5). The remaining storage series are relatively evenly distributed.

The high water loss in August may be related to recent spawning and that they therefore have a high content of mantle water in relation to the amount of mussel flesh and that they have a limited ability to retain the water because of their relatively bad condition and resistence.

High water loss may be explained by high temperatures. A contributing factor to the loss of water can be a variation in the mussel physiological activity. When the shells are brought ashore, they may find it more difficult to adjust during periods of high physiological activity. This would lead to difficulty in maintaining the mantle water. The comparatively high values of water loss in March, when compared with for instance June, may indicate this. Generally the mussels would be in good condition in March with an average content of mantle water and a lower temperature on land than in June. However, in March the physiological activity of the mussels is higher because of increasing temperatures in the water and ample nutritional supply (increased activity in the spring of algae) and because they are in an active production of sexual cells.

The lowest water loss during the year occurs in November. The cause (Page 82) is good conditions, lower temperatures and less nutritional intake with related reduced physiological activity. As well, the mussels are exposed to less stress due to the temperature conditions on shore when they are harvested.

Figure 24 presents the number of storage days which cause a 5% mortality. Figure 24 appears to indicate that the survivability is best in January and worst in March. Variations in survivability may be explained by variations in the resistance the mussels possess due to sexual maturing, spawning, temperature conditions, ability to prevent water loss, etc. Figure 25 presents a comparison between water loss and mortality after 16 days of storage.

By comparing the curves for sensory freshness and survivability (see Figure 26) during the year it can be seen that these two parameters, to some extent, follow the same trend. The method used indicates that the survivability exceeded the sensory freshness for large parts of the year. Various changes in conditions throughout the year cause some periods to produce mussels which do not maintain the sensory quality well during storage, even if their survivability is relatively high. Accordingly, it appears that survivability cannot be used as an indicator for sensory freshness.

Figure 19 shows total volatile nitrogen in steamed mussel flesh plotted as a function of week number for unstored and stored mussels. The figure indicates that the content of TVN varies throughout the year. It also appears as if those shells which have a high TVN content at the beginning of the storage period will maintain this level throughout the storage period. One cause, previously mentioned, may be that the physiological activity of the mussels and their metabolism varies throughout the year as a consequence of variations in availability of nutrients and temperatures. As well, the reproductive cycle of (Page 83) the mussel will also have an effect. The content of TVN in the mussel flesh may also, to some extent, be influenced by the mantle water content. High mantle water content will probably facilitate the separation of N.

TVN may also be related to bacterial activities. A comparison of TVN and the bacterial count through the year indicates that a high bacterial count in

unstored mussels coincides with a high content of TVN during March and October while, for instance, in June and August there is little correlation between these parameters.

Figure 20 shows the variations of pH during the year for fresh and stored mussels. pH appears to be highest during the cold season and lowest in the warm season. No conclusions can be drawn on the basis of these results because the data base is too sparse and the result may be coincidental.

The bacterial content (Figure 27) is highest in March and August - October and lowest in June and November. The variations are small, but may be related to variations in the mussel nutrient uptake during the year in that a higher filtration rate may lead to an increased content of bacteria in the mussels. The flourishing of algae in the spring and the increased temperature leads to a high nutritional intake. There is also rapid algae growth in the autumn. Since the temperature is then high, it is possible that the mussels also during this period have high nutritional intake in order to recuperate after spawning.

Variations in the amount of photoplankton and other nutrients in the (Page 84) water throughout the year may, to some extent, lead to variations in the bacterial content of the water, so that the mussels may also have a corresponding variation of bacteria. In waters close to the coast, however, there may be many reasons for variations in the bacterial count. It is therefore difficult to draw conclusions concerning these conditions.

In the storage series 18/4 and 13/6 small amounts of PSP were found in the mussels. These mussels were not subject to sensory tests.

Table 5 presents the metal content in the mussels. It is considered that the number of measurements was inadequate to clearly indicate changes in the metal content during the year. The results are presented here only to provide an indication of the general level of metals.

The food content is a most important quality objective. If one, in evaluating the common mussel quality as a function of the season, only considers the food content then the period April - June would clearly be the preferred harvesting season. However, the mussels should be harvested when the overall quality is best. It appears that the most suitable time for commercial harvesting of the common mussel may be a compromise between all the factors which determine the quality. A crucial factor in this regard is the danger of PSP. In addition, the mussel sensory freshness and survivability in dry storage are of major significance.

When the food content is highest then the risk of PSP is the greatest. As well, during this period the sensory freshness is not at its peak.

On the basis of the results from this study, and on what is known (Page 85) regarding the practices in other countries, commercial harvesting of the common mussel should occur during the cold season. At that time the mussels have begun to build up their food content and general condition following spawning, the content of total live bacteria is the lowest, the storage life and resistance is the greatest, while the danger for PSP at a minimum.

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